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ENHANCING CAPACITY FOR LOW EMISSION DEVELOPMENT STRATEGIES (EC-LEDS) CLEAN ENERGY PROGRAM

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MARKAL-Georgia EC-LEDS Reference Scenario Report

April, 2015

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April 2015

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ACRONYMS

BAU	Business-as-Usual
CH4	Methane
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
EC-LEDS	Enhanced Capacity – Low Emissions Development Strategy
GDP	Gross Domestic Product
Gg	Gigagram
GWh	Gigawatt Hours
GWP	Global Warming Potential
GHG	Greenhouse Gas
HPEP	Hydro Power and Energy Planning
Kt	Thousand Tons
Ktoe	Thousand Tons Oil Equivalent
LDV	Light Duty Vehicle
MARKAL	MARKet ALlocation
MW	Megawatts
N_2O	Nitrous Oxide
NMVOC	Non-methane volatile organic compounds
PJ	Petajoules
PJa	Petajoules per annum
REDP	Regional Energy Demand Planning
RES	Reference Energy System
RESMD	Regional Energy Security and Market Development
UNFCCC	United Nations Framework Convention on Climate Change
USAID	US Agency for International Development

BACKGROUND

This report is a condensed and updated version of the MARKAL-Georgia Reference scenario report delivered to Winrock International in September 2014. It summarizes the evolution of the Georgia energy system and the resulting GHG emissions under the Low Emission Development Strategy (LEDS) Business-as-Usual (BAU) scenario, which will provide the comparison point for assessing the costs and benefits of potential LEDS policy runs. The report documents information that has already been shared with the LEDS Expert Working Groups and is intended to enable other sectoral experts to review and comment on these results to ensure that best available local data and knowledge is embodied in MARKAL-Georgia. For all other material, regarding the improvements to the MARKAL-Georgia model for LEDS analyses, details of the Greenhouse Gas (GHG) accounting additions, and details of the MARKAL-Georgia model, please refer to the earlier report.

The LEDS BAU scenario is based on the Gross Domestic Product (GDP) and population growth assumptions highlighted in yellow in Table 1. The GDP growth rates were allocated equally to all demand sectors. All other parameters in the table are derived from these growth rates and the 2012 historical values.

The Annex to this report presents highlights of the energy and emissions results for three variants to the LEDS BAU scenario. These variants are based upon alternate projections of GDP and population, as requested by the Climate Change Office in the Ministry of Environment and Natural Resources Protection, the Ministry in Energy and the Ministry of Economy and Sustainable Development. Two of the alternate scenarios represent optimistic and pessimistic economic growth cases, and one uses specific GDP and population projections from the Climate Change Office.

An Excel workbook accompanies this report, which provides tabular values for all the charts presented in this report.

Table 1: GDP and Population Growth Assumptions for BAU Scenario

BAU Assumptions	2012	2015	2018	2021	2024	2027	2030	2033	2036
GDP growth		2.00%	6.00%	6.00%	6.00%	5.00%	5.00%	5.00%	5.00%
Population growth		0.50%	0.50%	0.50%	0.50%	0.25%	0.25%	0.25%	0.25%
GDP (2012M Euro)	12,323	13,077	15,575	18,550	22,093	25,576	29,607	34,274	39,676
Population (1000s)	4,498	4,565	4,634	4,703	4,774	4,810	4,846	4,883	4,920
GDP/pop	2.740	2.865	3.361	3.944	4.627	5.317	6.109	7.019	8.065

MARKAL-GEORGIA OVERVIEW

The MARKAL-Georgia model has been developed over several years with the support of a series of US Agency for International Development (USAID) regional and national projects, and is designed to inform policy making and assess future energy investment options. It was constructed using the MARKAL integrated energy system modeling platform, developed under the auspices of the International Energy Agency's Energy Technology Systems Analysis Program (www.iea-etsap.org). The MARKAL-Georgia model has been previously used to examine the role of energy efficiency and renewable energy in meeting anticipated Energy Community commitments and European Union accession directives. The model was recently updated and applied as part of the USAID Hydro Power and Energy Planning (HPEP) project, and further updating and refinements have been undertaken as part of this EC-LEDS project. In addition, capacity is being built within the Ministry of Energy's Analytical Department with an eye towards their long-term stewardship and ongoing use of the model to advise policy and planning.

Key features of MARKAL models are:

- Encompasses an ***entire energy system*** from resource extraction through to end-use demands as represented by a Reference Energy System (RES) network (see Figure 1);
- Employs least-cost ***optimization****;*
- Identifies the most ***cost-effective*** pattern of resource use and technology deployment over time;
- Provides a framework for the evaluation of mid-to-long-term ***policies and programs*** that can impact the evolution of the energy system;
- Quantifies the ***costs and technology choices****, and the associated emissions,* that result from imposition of the policies and programs, and
- Fosters ***stakeholder buy-in*** and consensus building.

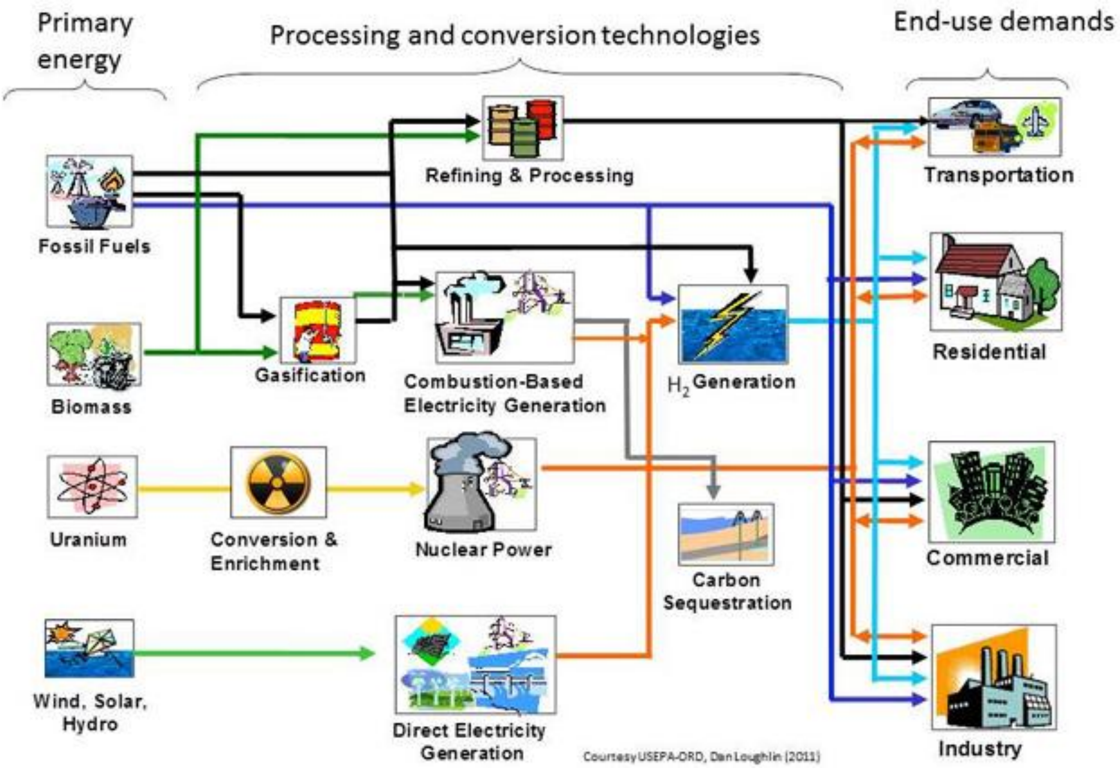

Figure 1: Simplified Reference Energy System

LEDS BUSINESS AS USUAL (BAU) SCENARIO

The BAU scenario represents the expected evolution of the Georgia energy system under current policies and practices. This report presents details of the energy consumption and GHG emissions resulting from the total energy system. Non-energy emissions are tracked, but not currently reported as sectors working groups have not been able to provide the needed starting point data.

The MARKAL-Georgia BAU energy supply and consumption pathway serves as the comparison scenario for quantifying the costs, benefits, technology changes, fuel switching and other impacts of potential LEDS strategies.

The report presents the total energy system according to the following energy sectors:

- Fuel supply and electricity generation;
- Buildings (households and commercial);
- Industry;

- Transportation, and
- Agriculture.

1.1 Fuel Supply and Electricity Generation

Figure 2 shows a simplified RES diagram for the upstream and electricity supply sector as depicted in the MARKAL-Georgia. The upstream portion of the energy system is comprised of domestic energy supplies (e.g., coal mining, natural gas wells), imports of electricity, natural gas and oil products, and renewable energy resources. For each of the electricity generation types shown there may be several instances identifying individual power plants. The electricity transmission and distribution networks in Georgia are also represented, along with imports and exports to four neighboring countries.

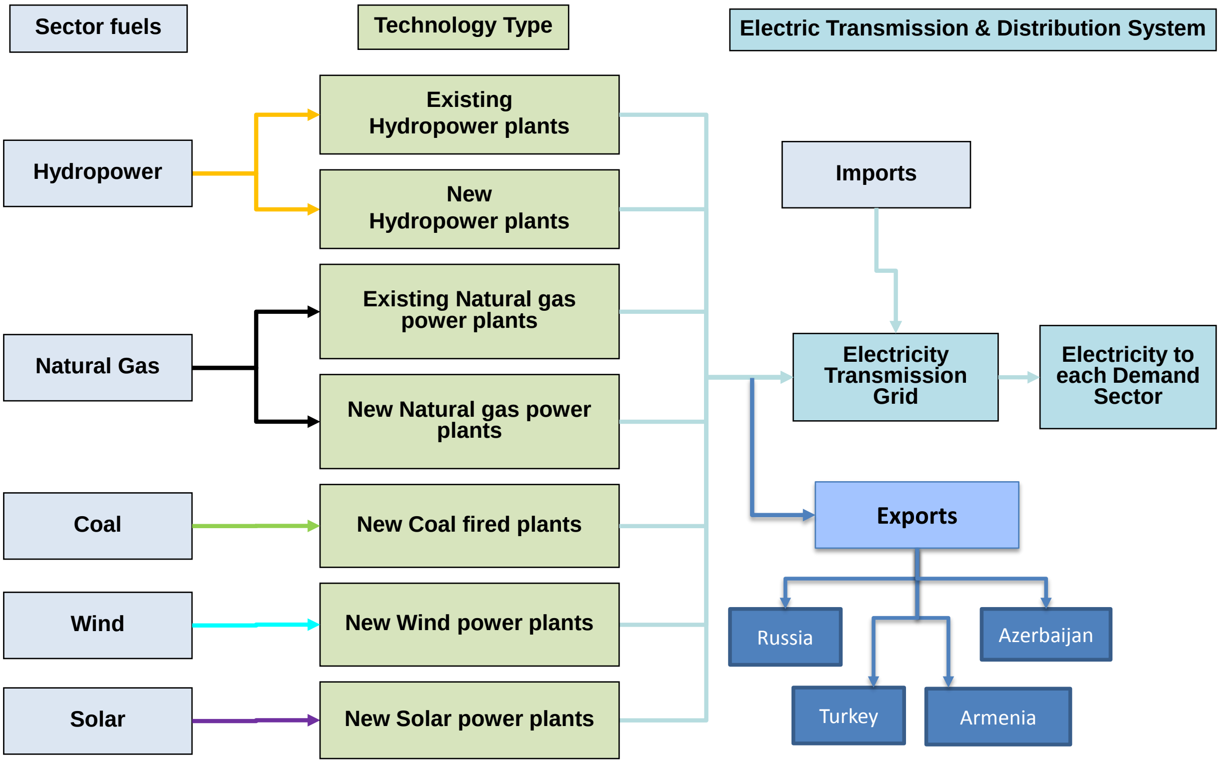

Figure 2: Fuel Supply and Electricity Generation RES

As shown in

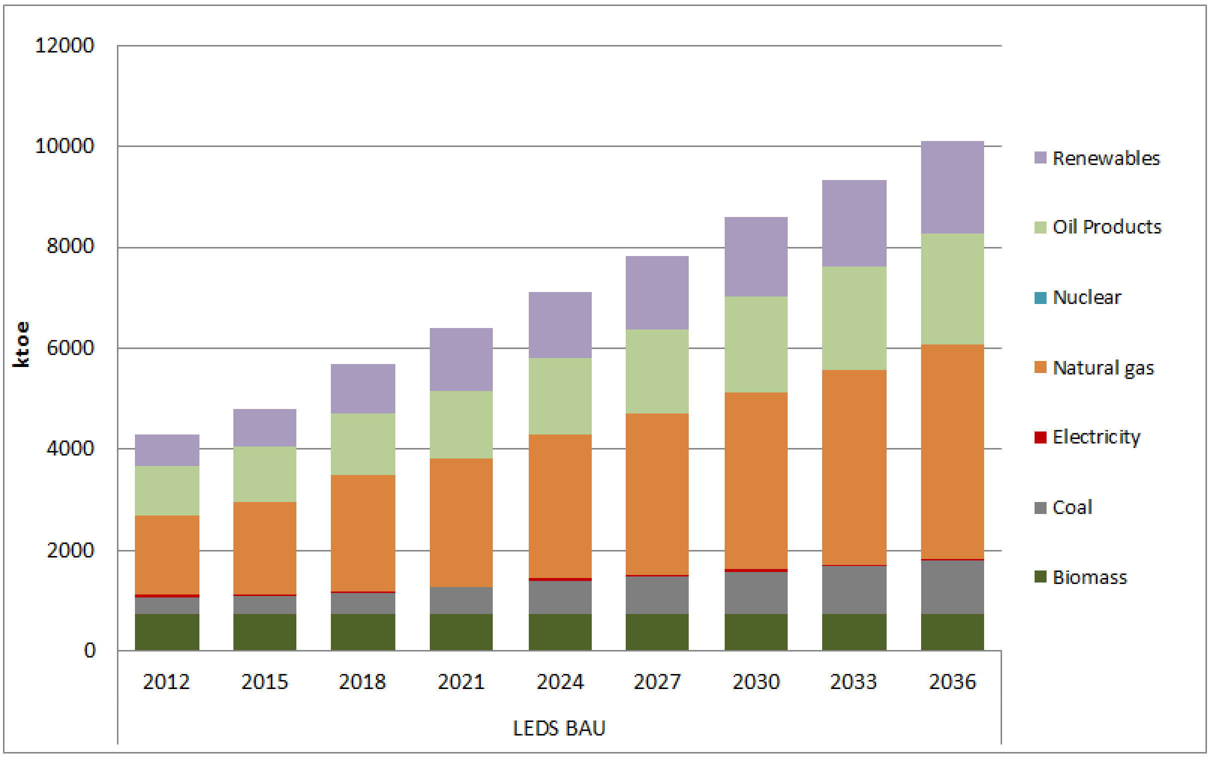

Figure 3, in the BAU scenario total primary energy use increases 135% from 2012 to 2036 with most of the growth occurring for natural gas (2650 ktoe), oil products (1235 ktoe), renewables (1200 ktoe) and coal (740 ktoe).

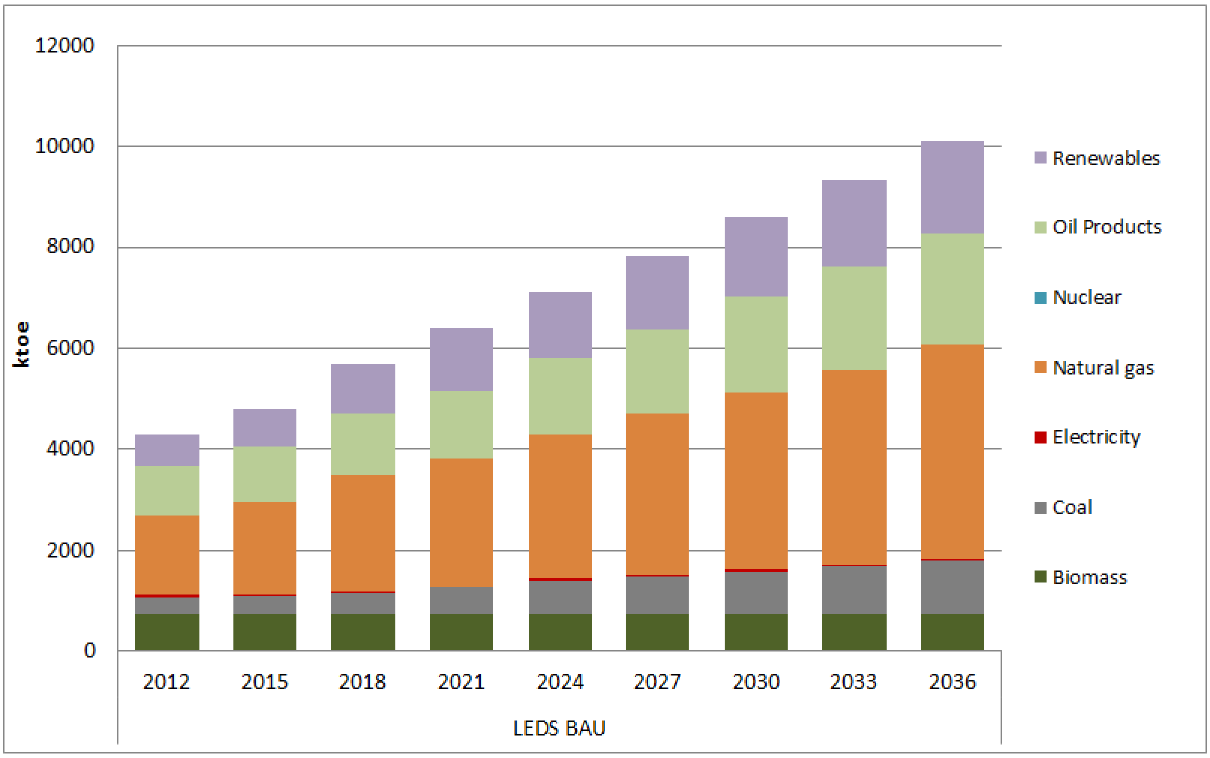

Figure 3: Primary Energy Production and Imports

As shown in Figure 4, total electricity generation increases 180% from 2012 to 2036 with most of the growth occurring from hydropower (13,800 GWh), natural gas (2875 GWh) and coal (440 GWh). Annual electricity imports average about 500 GWh.

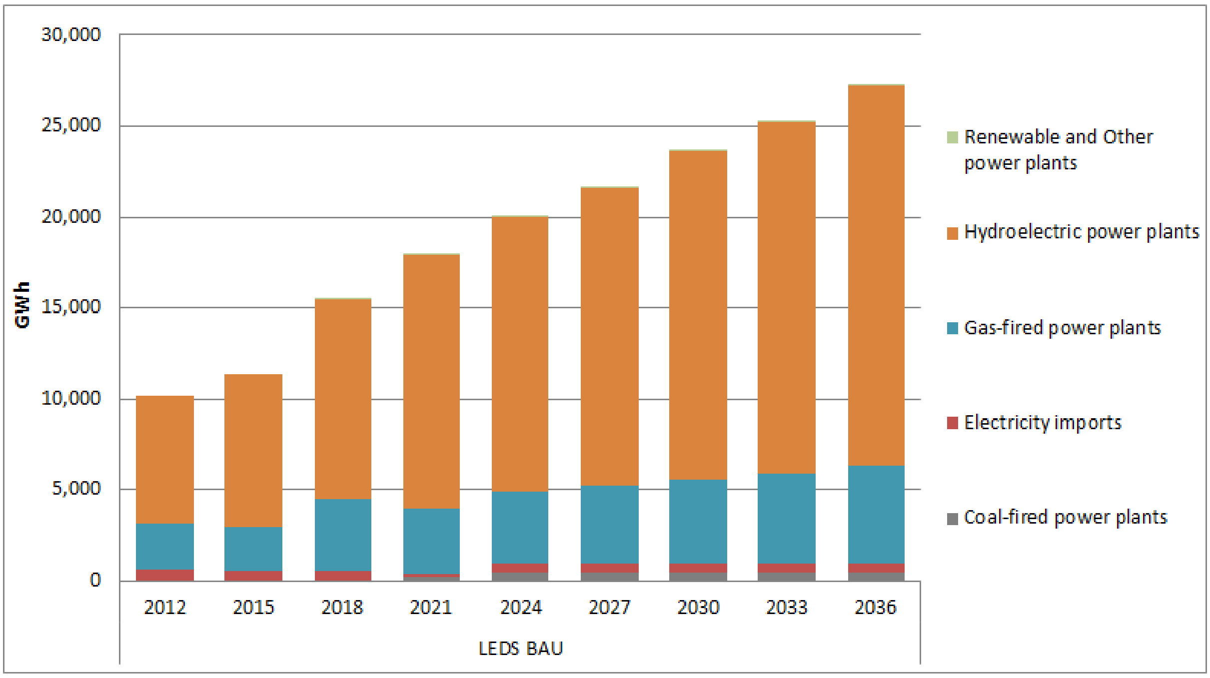

Figure 4: Electricity Generation by Plant Type

Figure 5, which provides new power plant capacity installed in each 3-year period, shows that the BAU scenario adds hydropower in every period, along with a 220 MW gas-fired plant and a 20 MW wind farm in 2018, followed by a 120 MW coal plant in 2021. These three non-hydro power plants are planned builds that are specified as part of the BAU scenario.

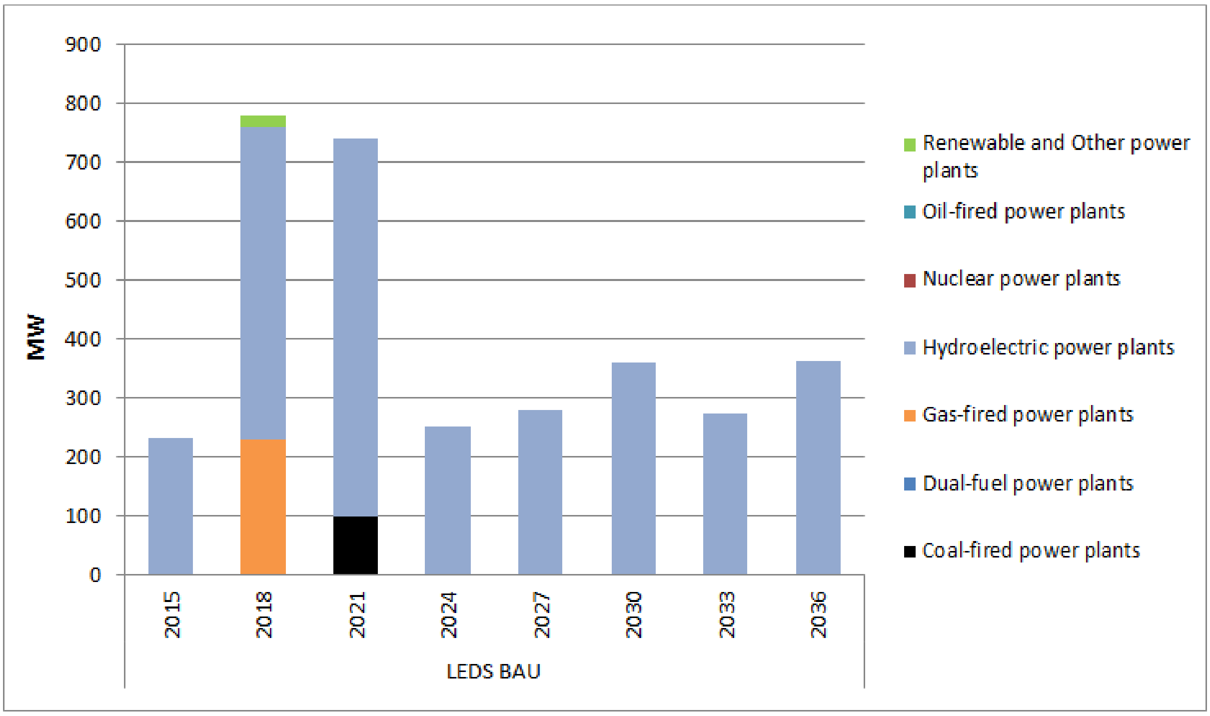

Figure 5: Capacity of New Power Plant Additions (per period)

Figure 6 shows that because the gas-fired power plants are required to provide a fixed percentage of total electricity consumption for load balancing the expanding hydropower capacity, the gas consumption for power generation increases by almost 120% by 2036. It also shows the addition of the planned new coal plant in 2021.

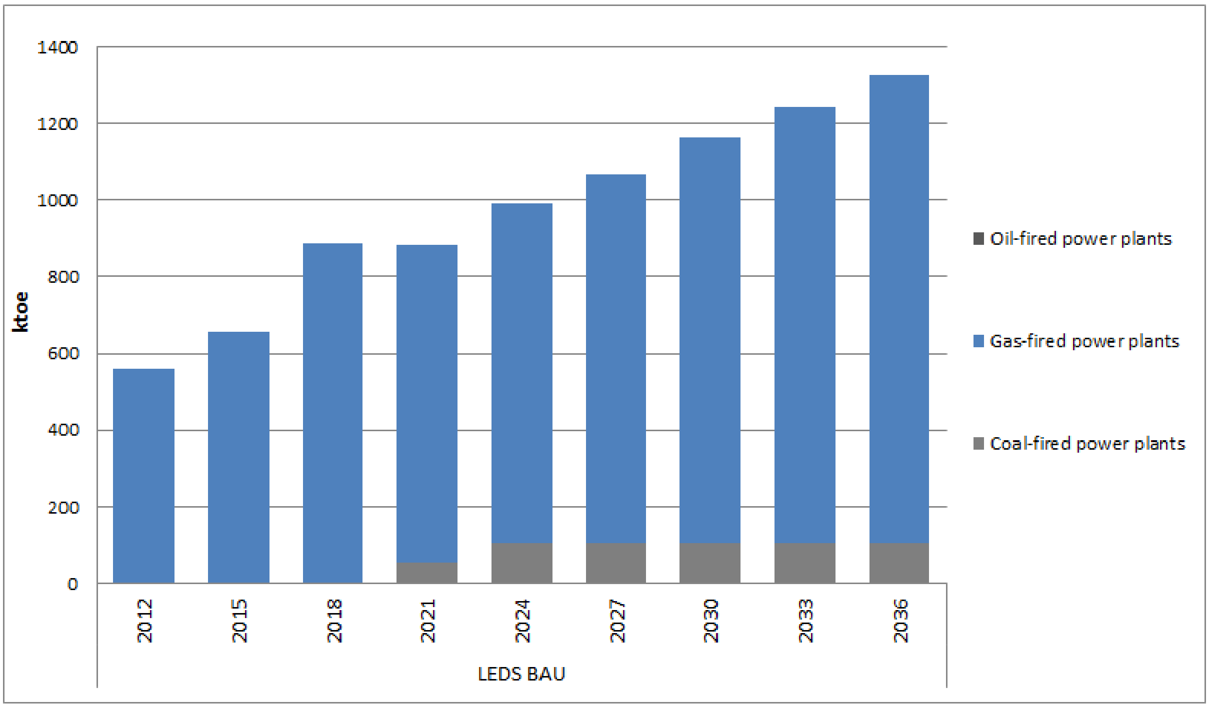

Figure 6: Power Plant Fuel Consumption

1.2 Energy Sector GHG Emissions

The energy related GHG emissions are directly tied to the delivery and consumption of fossil fuels, where in Georgia natural gas makes up the largest share. Figure 7 shows natural gas consumption by sector, with consumption for the residential sector increasing the most (1000 ktoe), followed by power generation (660 ktoe) and transportation (420 ktoe).

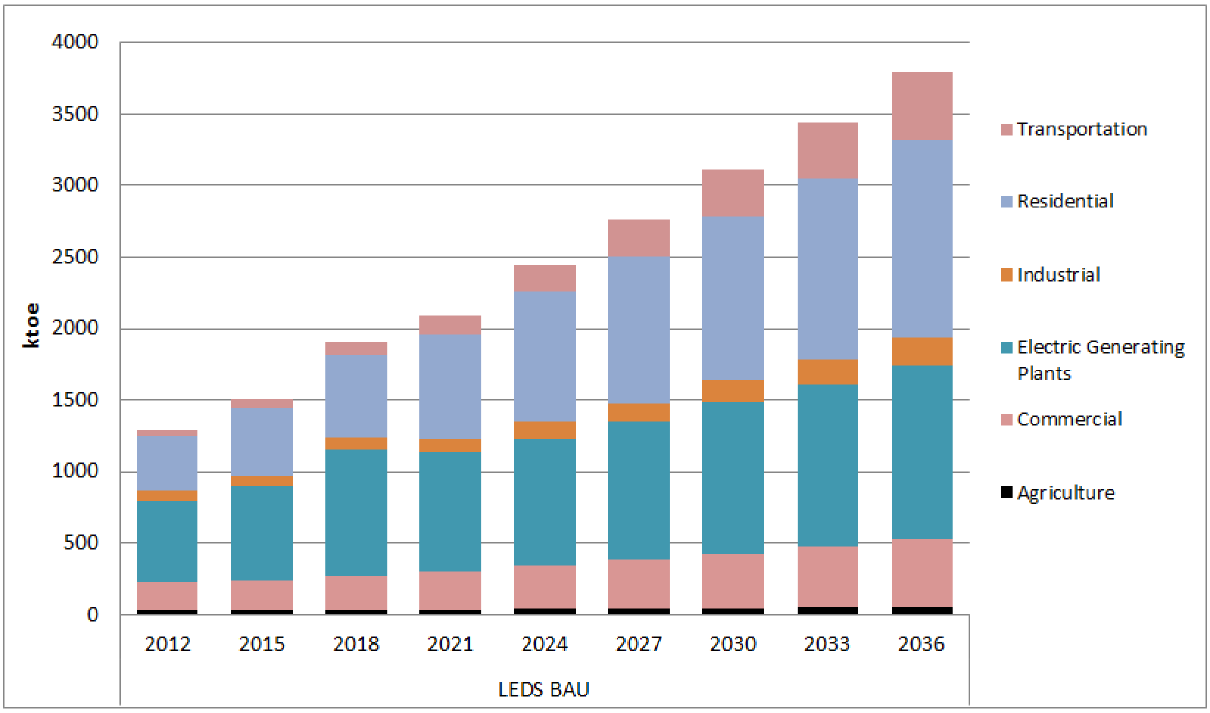

Figure 7: Consumption of Natural Gas by Sector

Total final energy use increases by 140% between 2012 and 2036 with most of the growth occurring for transportation (1,620 ktoe), residential (1,520 ktoe) and industry (1,130 ktoe) sectors. Figure 8 shows final energy use by fuel type. The greatest growth is in natural gas use, which grows from 20% of the total to 30% by 2036. Electricity, coal, gasoline and diesel also show significant growth.

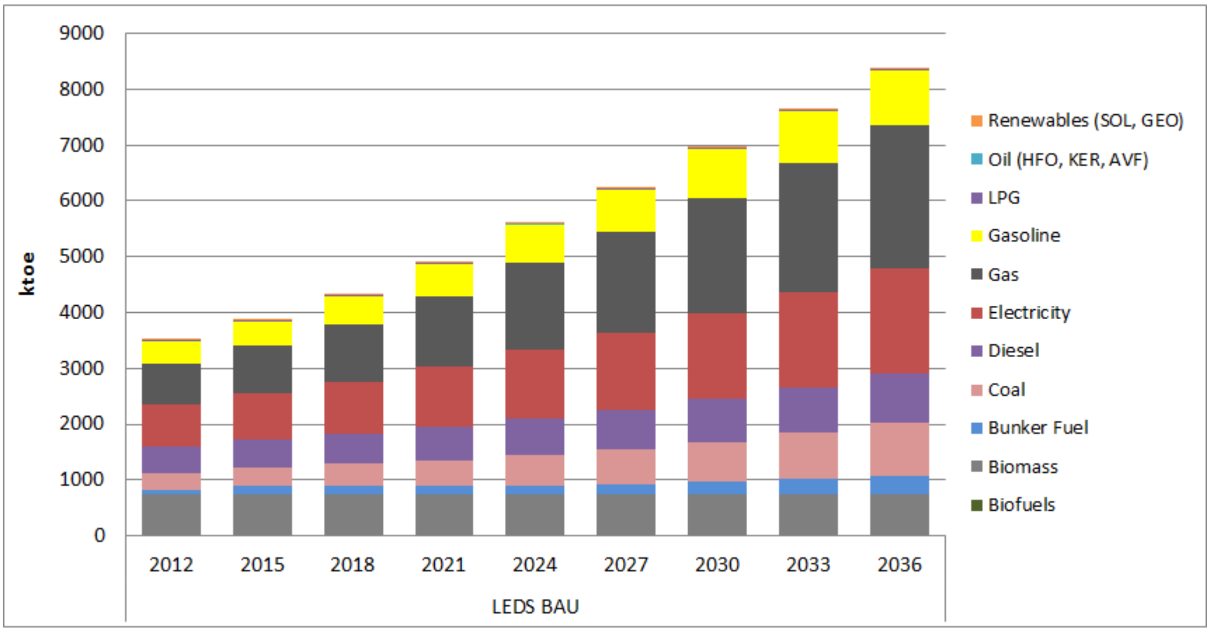

Figure 8: Final Energy Consumption

As shown in Figure 9, CO_2 emissions from the entire energy system increase by 170% between 2012 and 2036 led by the transportation sector (increasing 3,700 kt), the industry sector (increasing 3,200 kt) and the residential sector (increasing 2,350 kt). Power sector emissions increase by 1990 kt.

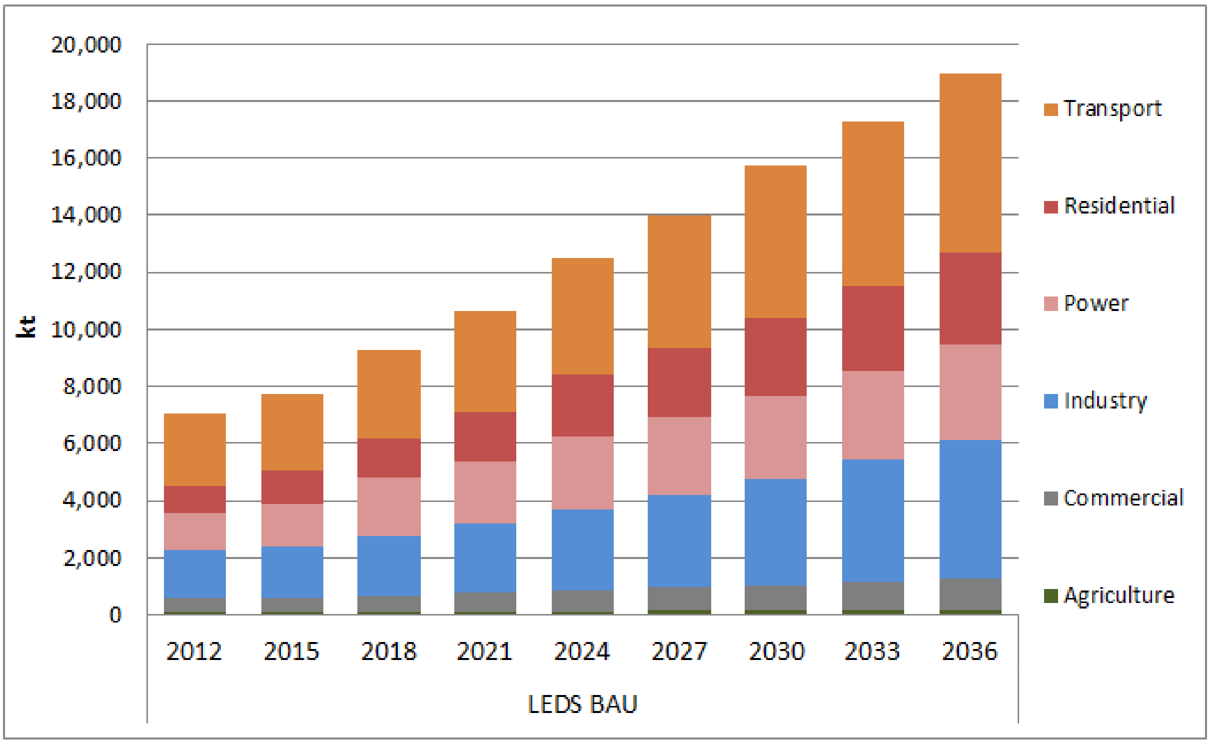

Figure 9: CO_2 Emissions by Sector

Figure 10 shows that methane emissions from the entire energy system increase by almost 150% between 2012 and 2036 with natural gas pipelines comprising 90% of the total (increasing 120 kt), while the other methane emission sources remain flat.

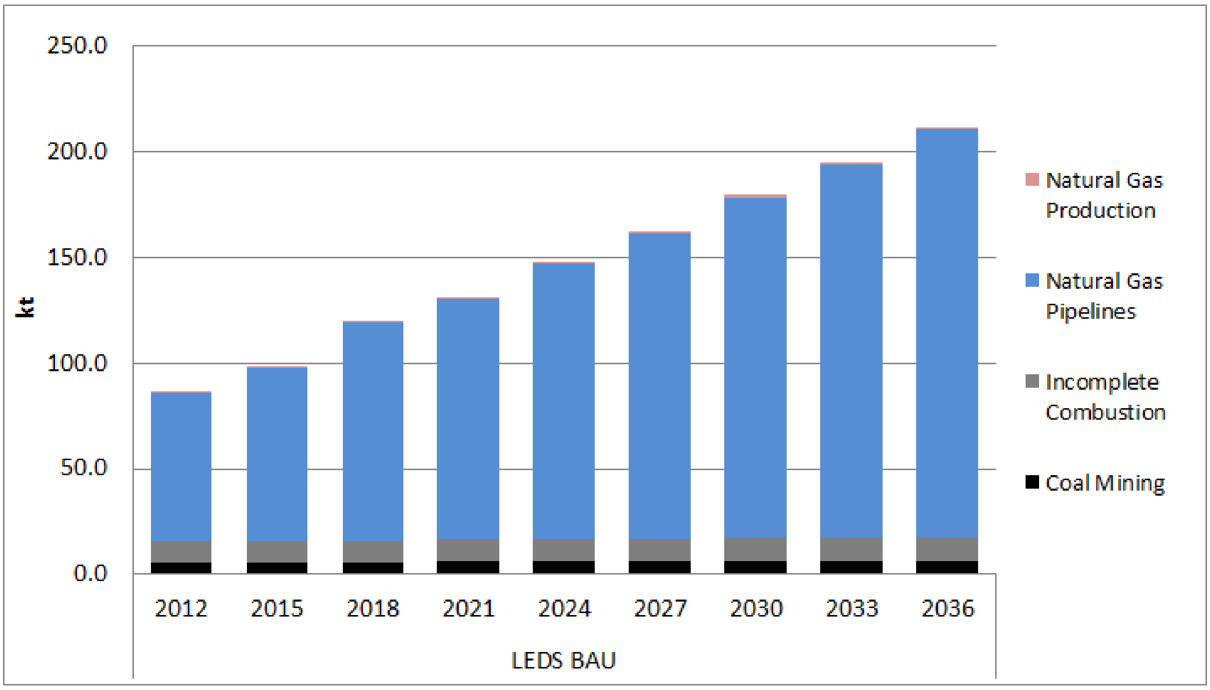

Figure 10: Methane Emissions by Activity

Figure 11 shows N_2O emissions from the energy system, which are due to the incomplete combustion of fuels. These emissions grow at a rate similar to final energy use.

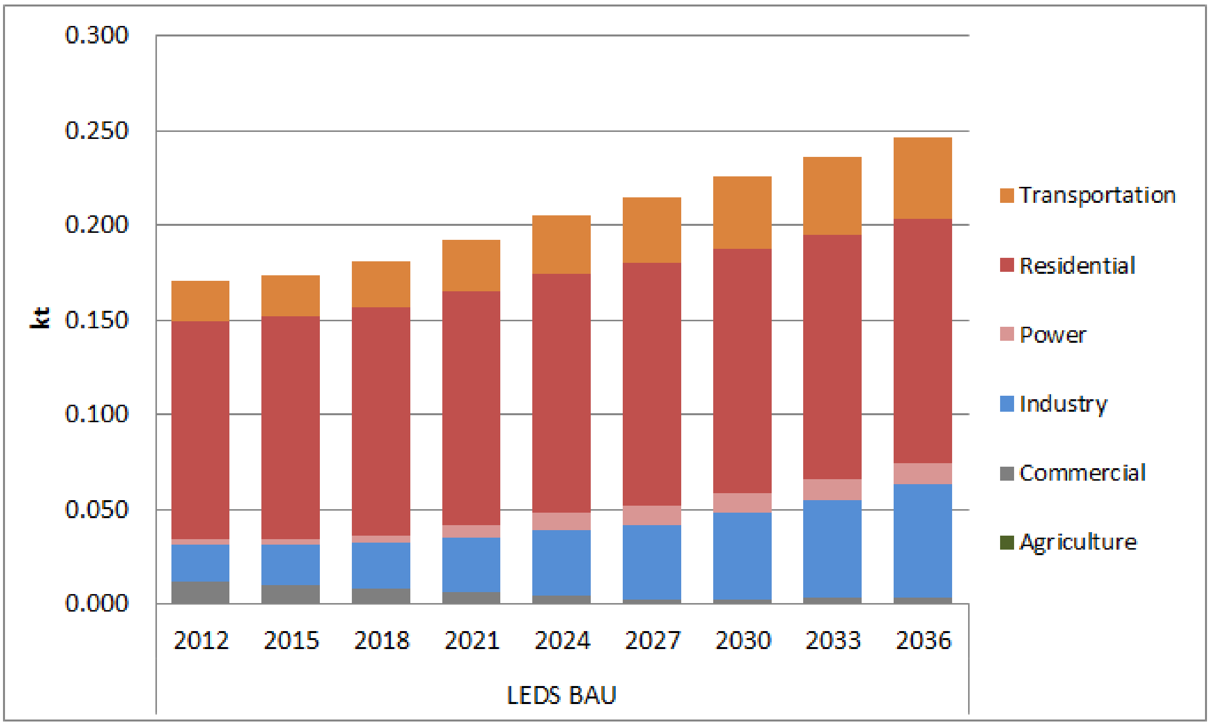

Figure 11: N_2O Emissions by Sector

CO_2 equivalent emissions from the entire energy system are presented in Figure 12, which shows that about 80% of total GHG emissions are due to CO_2 from fuel combustion and that about 20% are due to methane emissions from coal mines and natural gas pipelines, with a very small contribution from N_2O.

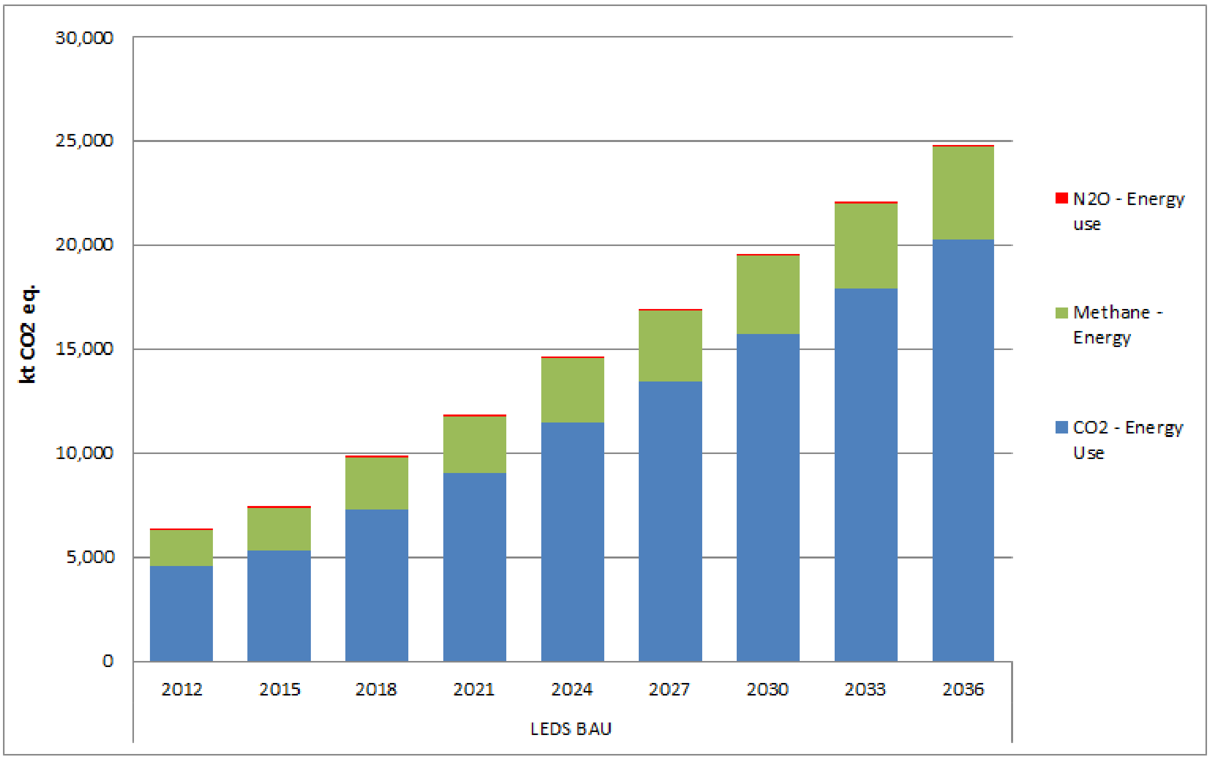

Figure 12: CO_2 equivalent GHG Emissions by Type

1.3 Building Sectors Energy Use and Direct Emissions

In MARKAL-Georgia the buildings sector consists of both commercial (government and services) and residential (households) buildings. A simplified RES diagram of the commercial sector is presented in Figure 13, and shows the fuels, technology types and end-use services included in the model. In addition to energy efficient devices for all the technologies identified, the model also includes retrofit measures to reduce overall building energy demand.

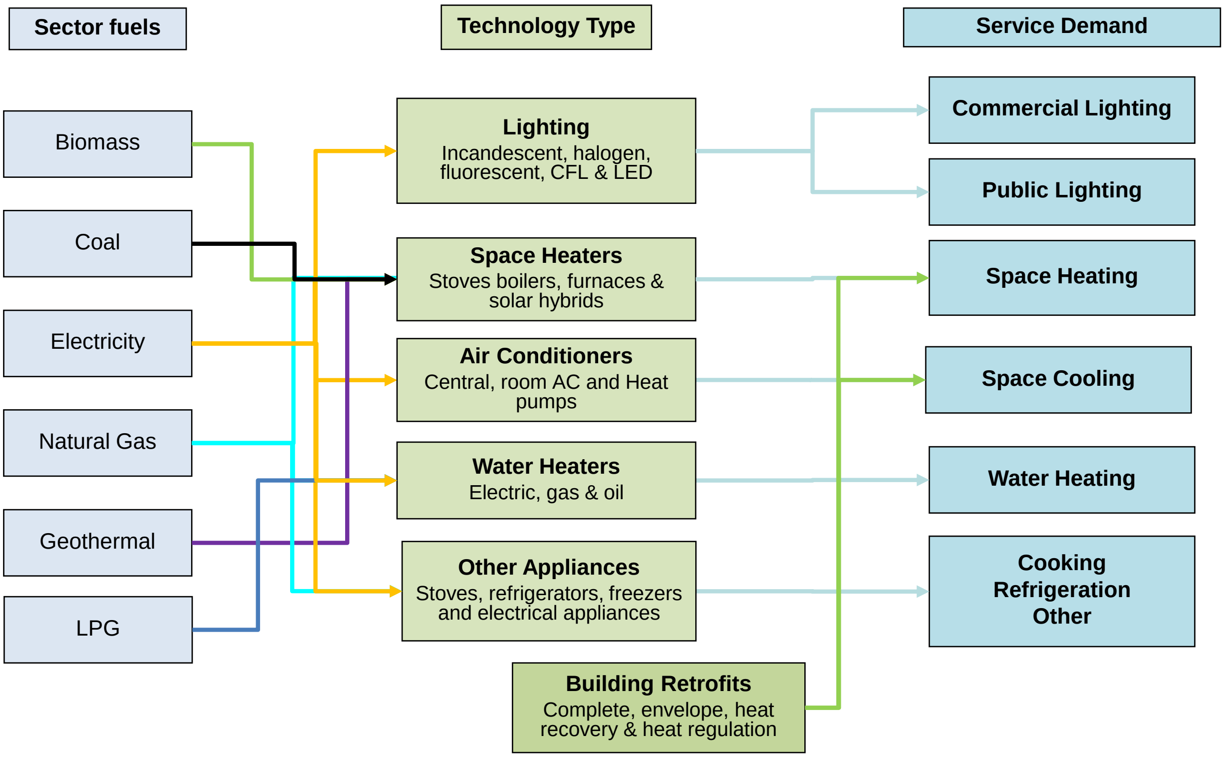

Figure 13: Commercial Buildings RES

As shown in Figure 14, commercial sector energy use increases most significantly for natural gas (270 ktoe) and electricity (180 ktoe), with biomass use declining.

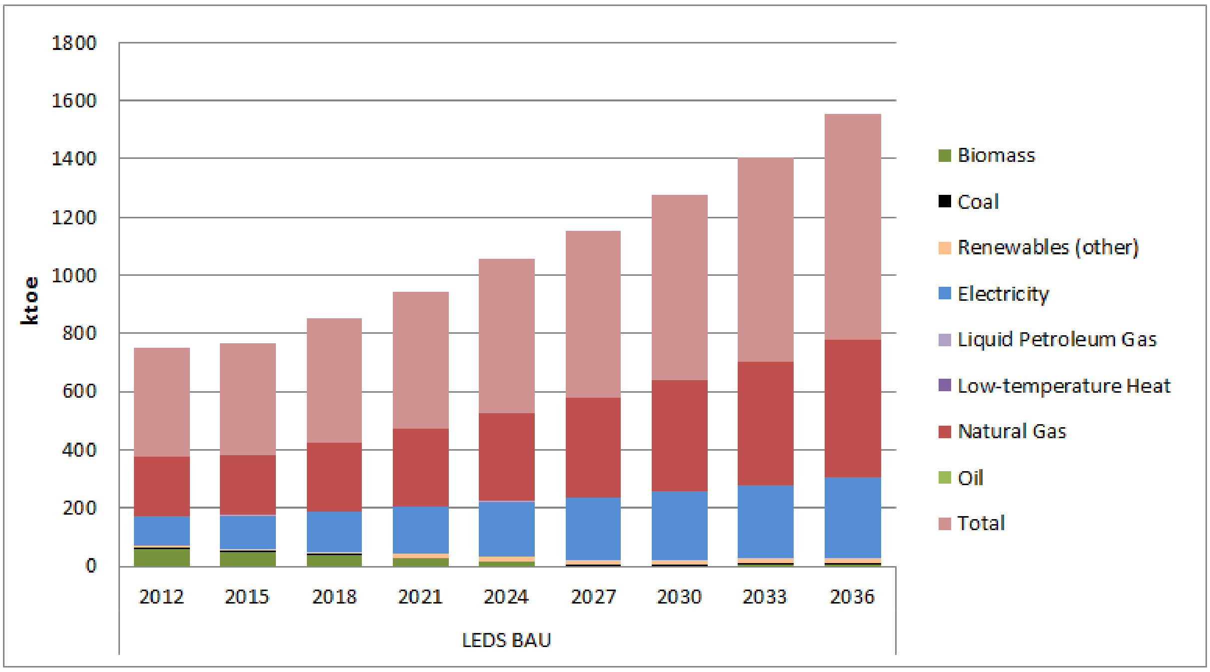

Figure 14: Commercial Energy Use by Fuel Type

Figure 15, shows that commercial energy use by end-use service, is dominated by space heating (increasing 190 ktoe) and water heating (increasing 80 ktoe). Space heating declines from a 66% to a 57% share while water heating increases from 10% to 15% with space cooling and other electric appliances also increasing their shares.

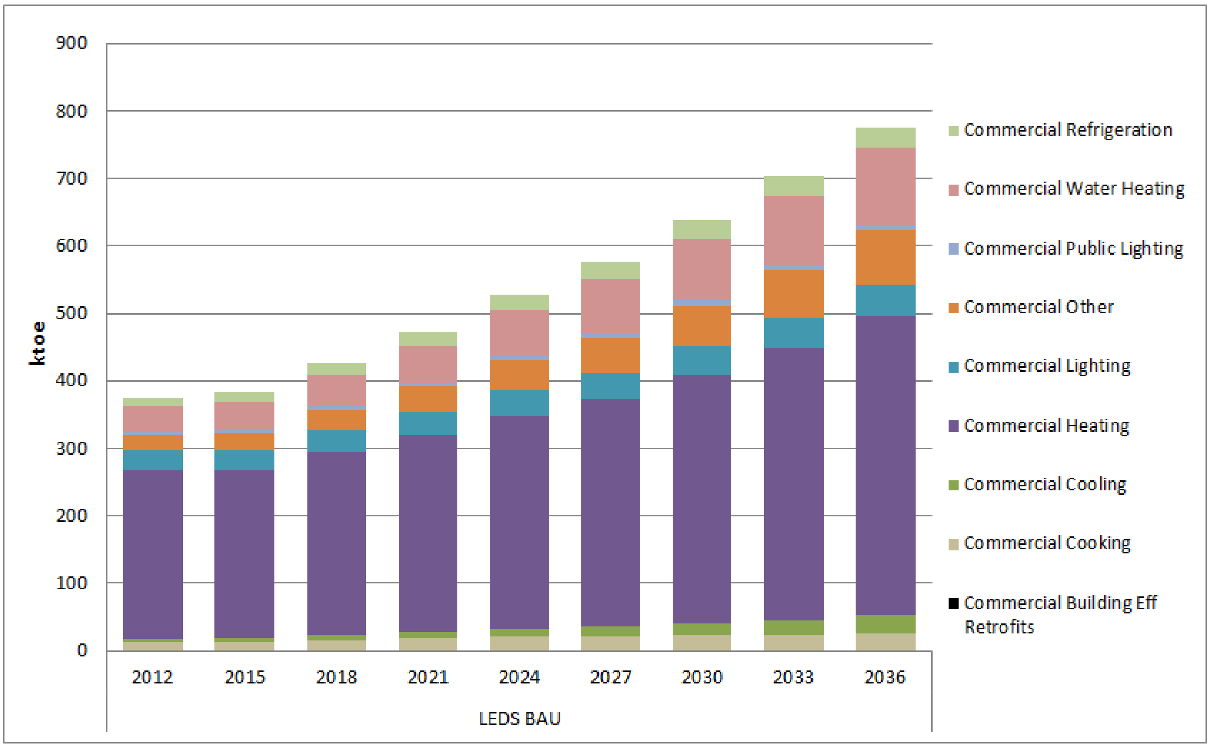

Figure 15: Commercial Energy Use by Energy Service

Figure 16, which provides CO_2 emissions from commercial sector energy use, shows these emissions are also dominated by space heating (increasing 485 kt) and water heating (increasing 150 kt).

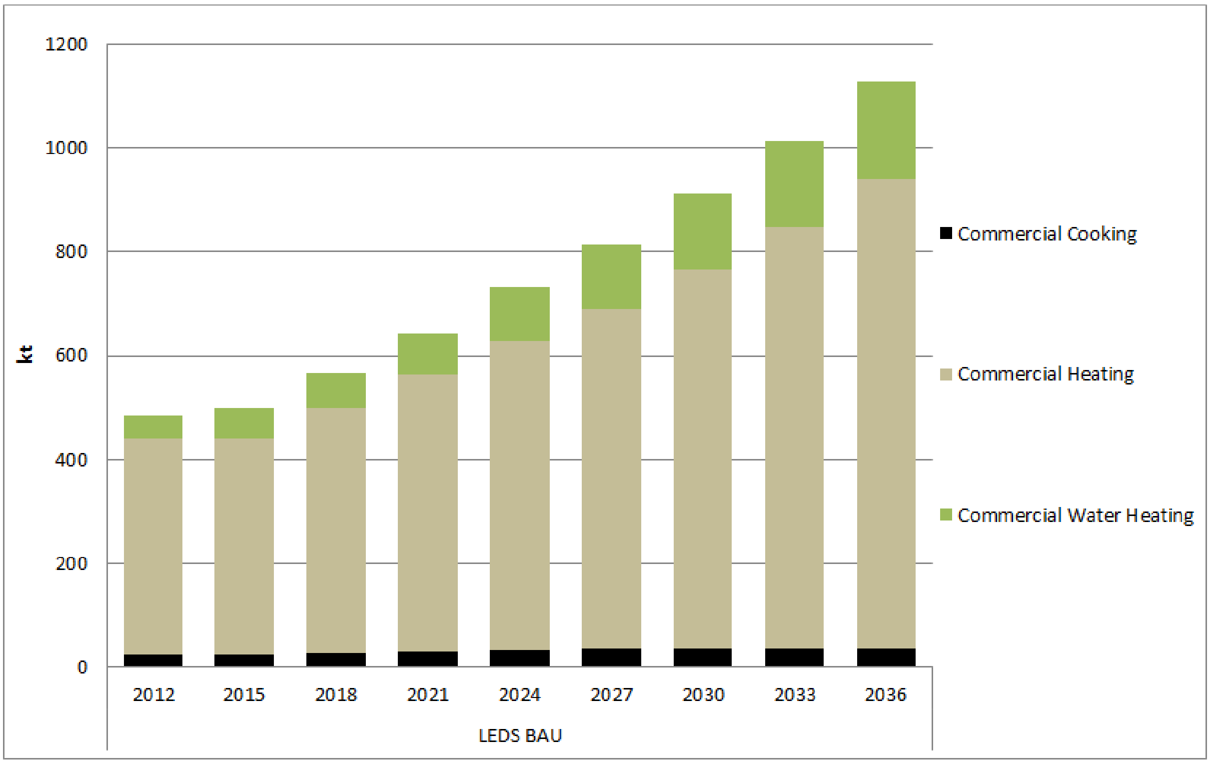

Figure 16: Commercial Emissions by Energy Service

A simplified RES diagram of the residential sector is presented in Figure 17, and shows the fuels, technology types and end-use services included in the model. In addition to energy efficient devices for all the technologies identified, the model also includes insulation measures to reduce overall building energy demand.

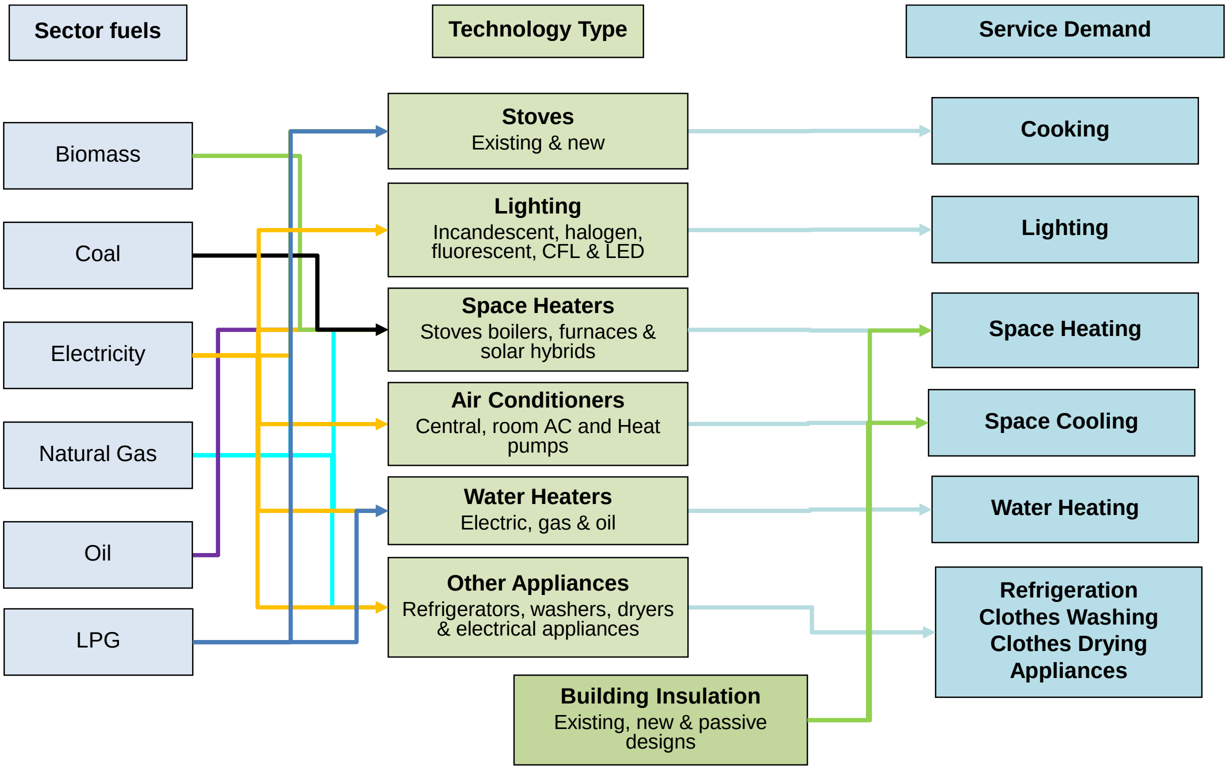

Figure 17: Residential Buildings RES

Residential sector energy use, which is shown in Figure 18, increases most significantly for natural gas (1000 ktoe) and electricity (450 ktoe). The natural gas share increases from 27% to 47%, while biomass share reduces from 48% to 25%. The electricity share increases from 22% to 26%.

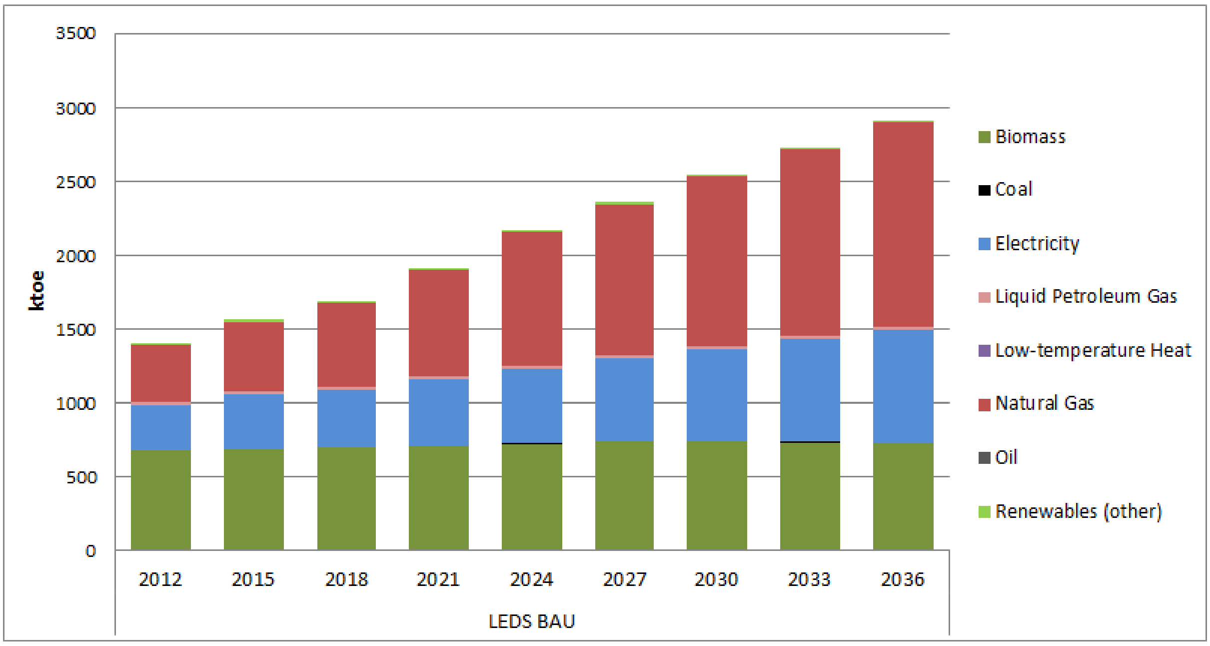

Figure 18: Residential Energy Use by Fuel

Figure 19 shows that residential sector energy use is dominated by space heating (increasing 670 ktoe), water heating (increasing 340 ktoe) and cooling (increasing 140 ktoe).

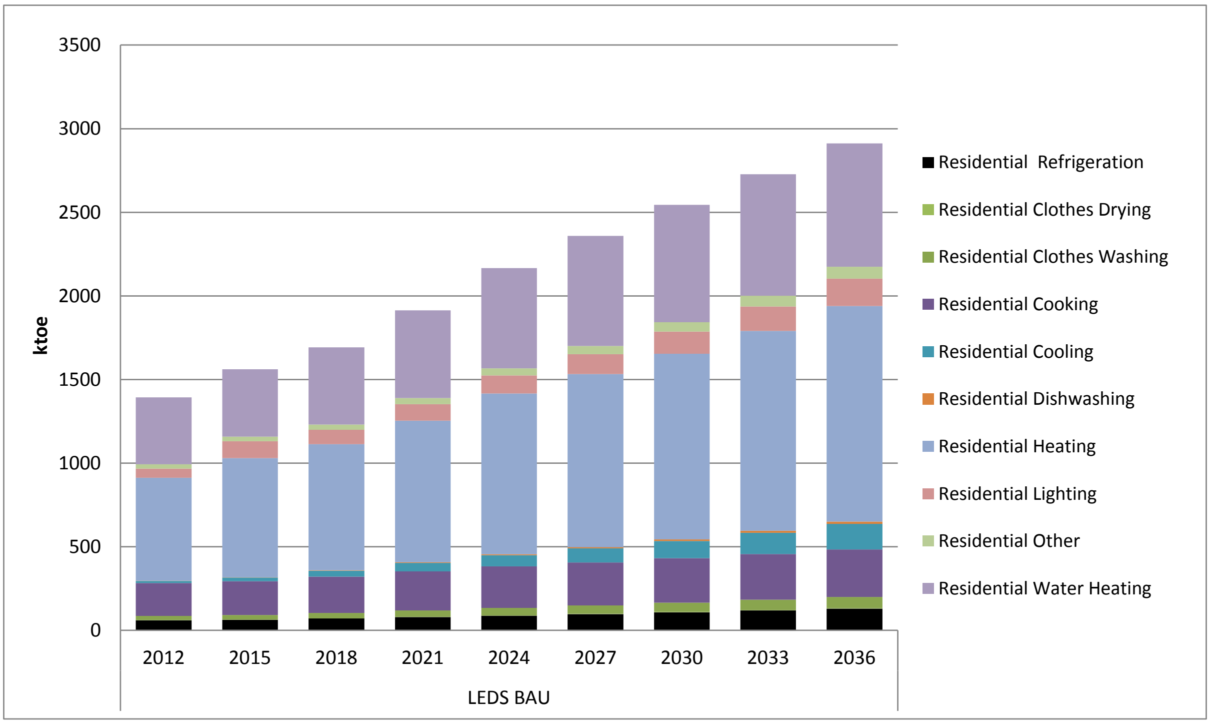

Figure 19: Residential Energy Consumption by Use

As shown in Figure 20, the growth in CO_2 emissions from residential sector energy use is dominated by space heating and water heating, with emissions from cooking growing slightly.

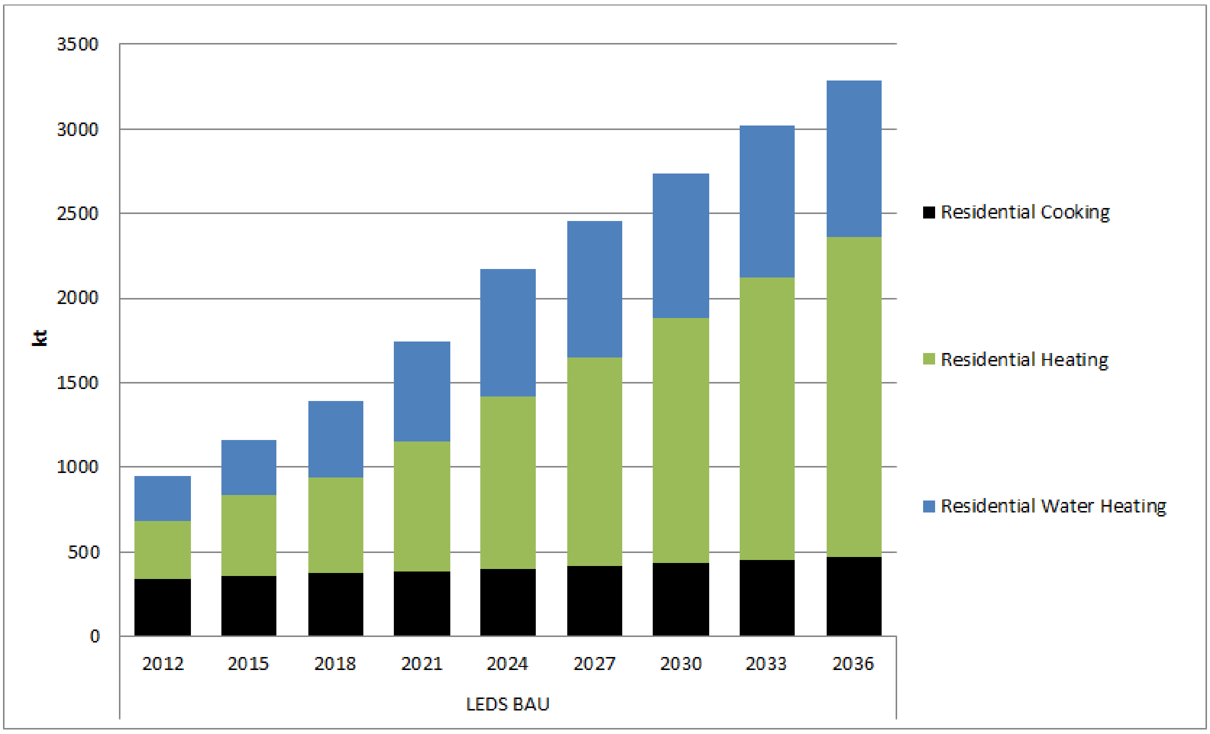

Figure 20: Residential Emissions by Energy Service

1.4 Industry Sector Energy Use and Direct Emissions

The simplified RES for the Industrial sector is shown in Figure 21. Each industrial sub-sector requires process heat and mechanical drive services to produce their associated products.

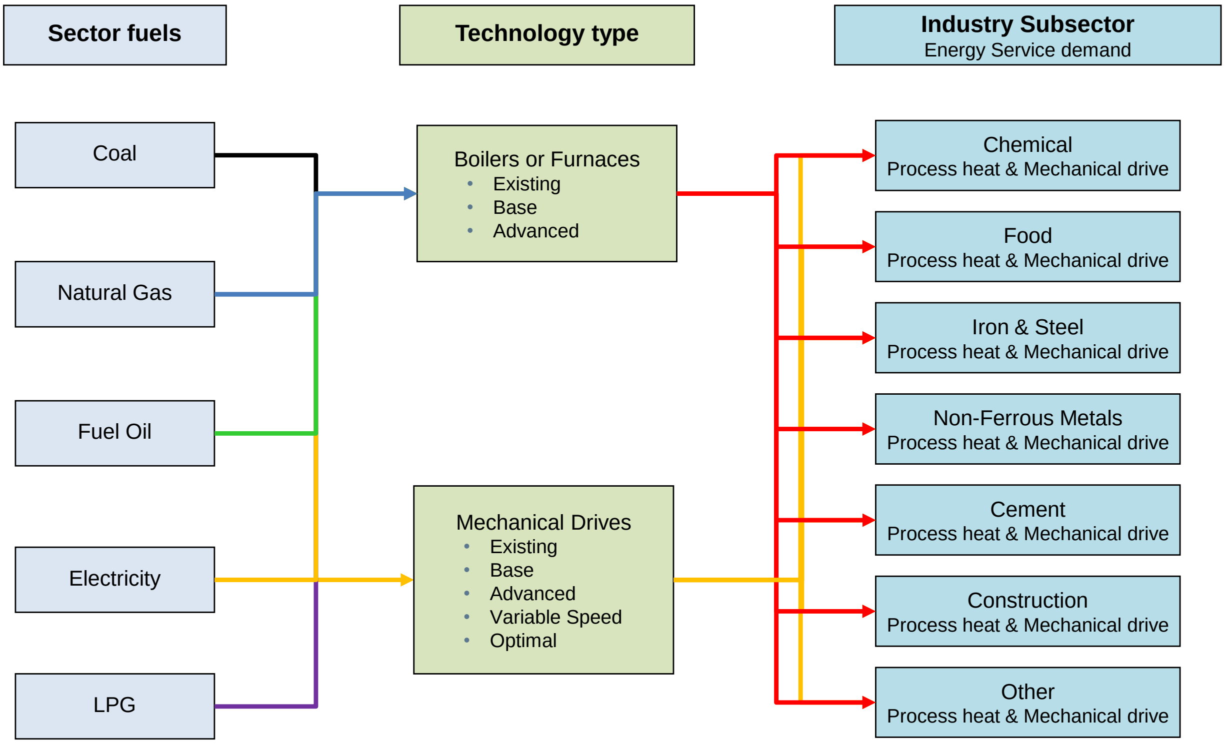

Figure 21: Industry Sector RES

As shown in Figure 22, industrial energy use grows by 180% between 2012 and 2036. Although Non-metallic minerals (cement) and iron & steel are the largest, each industrial subsector grows proportionally, as the demand projection for each sector is determined by the same GDP and elasticity drivers.

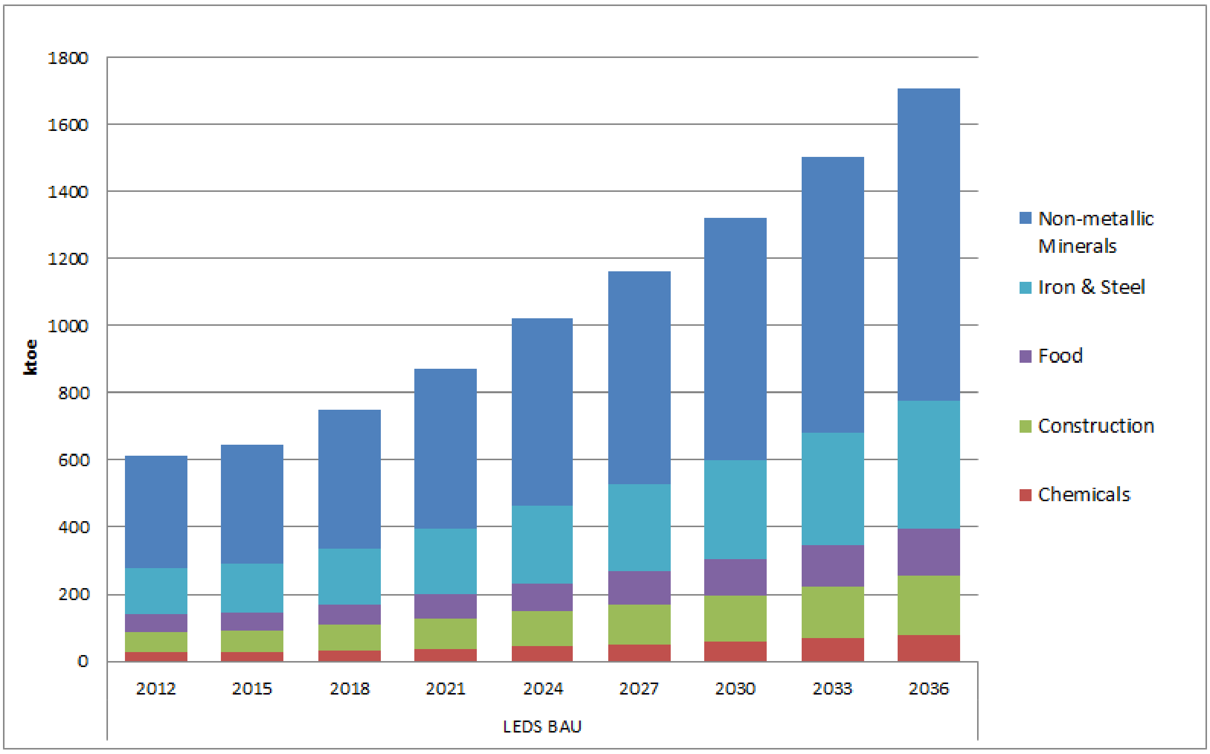

Figure 22: Industrial Energy Use by Subsector

As shown in Figure 23, coal comprises 50% of industrial energy use, followed by electricity (28%). As a result, the primary GHG emissions from the sector come from coal and natural gas use.

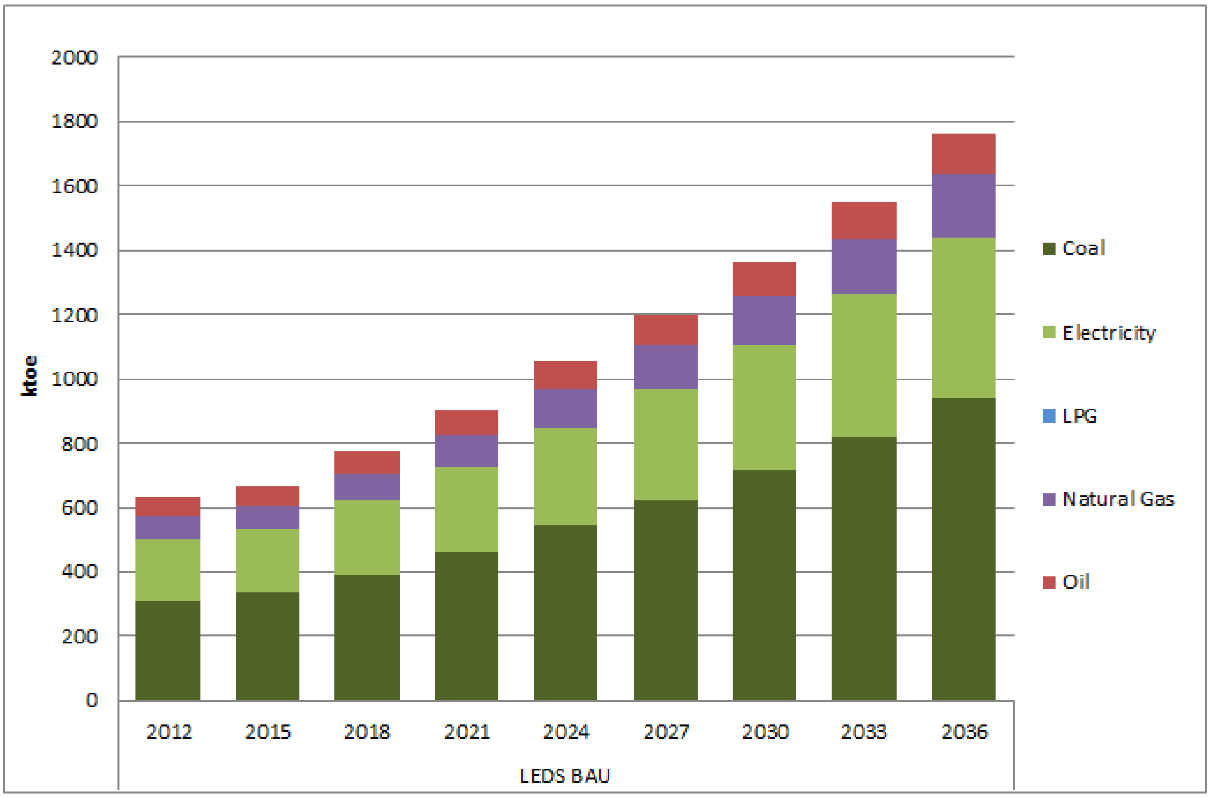

Figure 23: Industrial Energy Use by Fuel

Figure 24 shows that industry sector CO_2 emissions come primarily from cement production (65%), with all other subsectors accounting for less than 10% each.

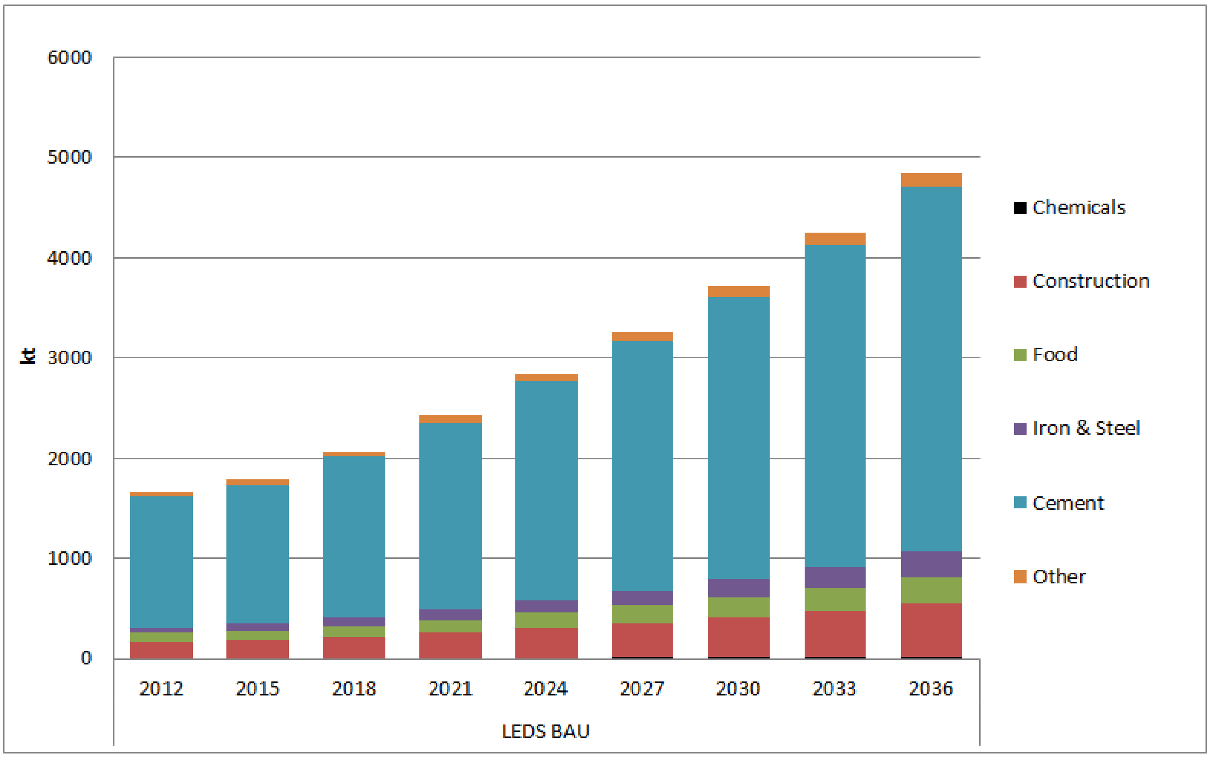

Figure 24: Industrial CO_2 Emissions by Sector

1.5 Transportation Sector Energy Use and Direct Emissions

The simplified RES for the passenger Transportation is shown in Figure 25. Each passenger transportation demand uses a suite of vehicle types to deliver the associated service.

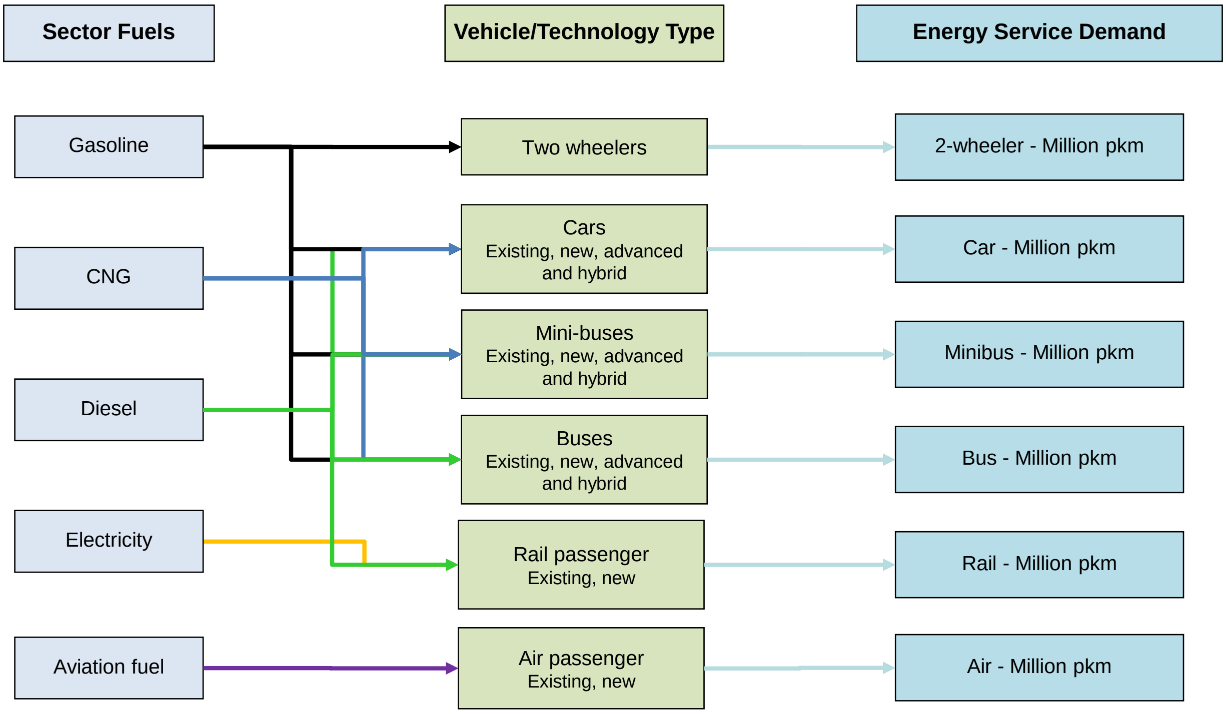

Figure 25: Transportation Passenger Travel RES

As shown in Figure 26, total transport sector fuel use, which is dominated by gasoline and diesel consumption, increases by 170% between 2012 and 2036. Gasoline use grows faster than diesel use and natural gas (CNG) use grows by (440 ktoe), a 10 fold increase, with most used in Light Duty Vehicles (LDVs).

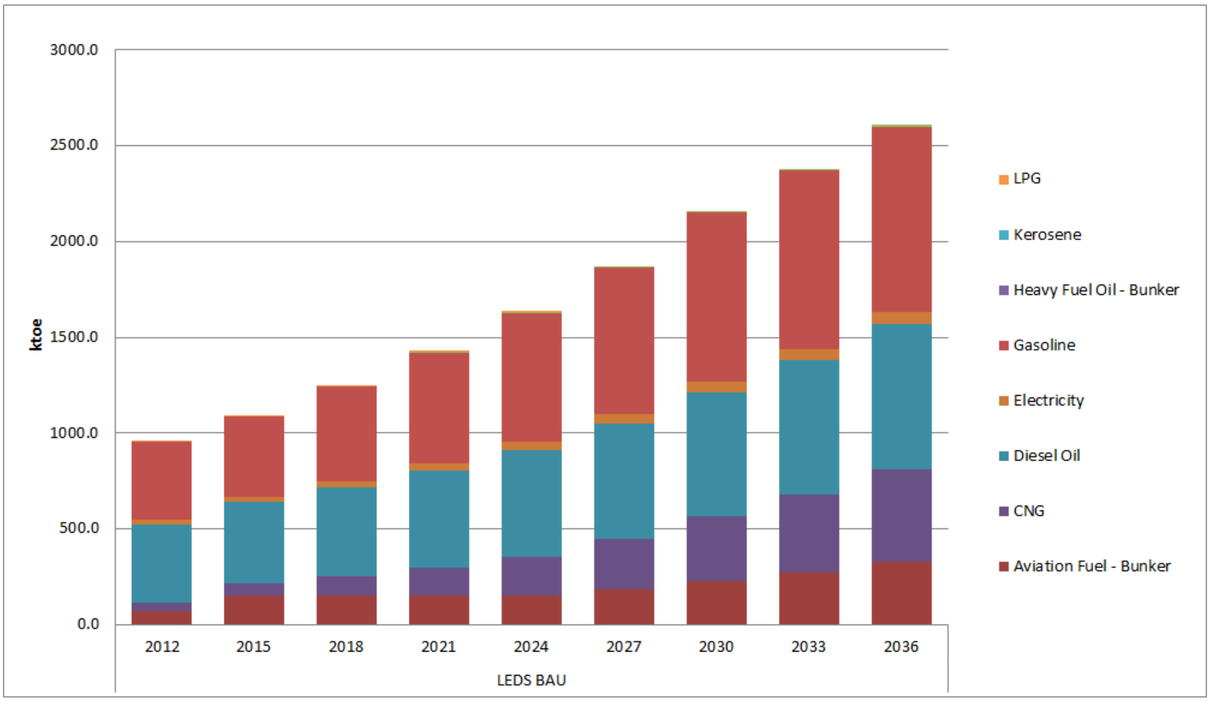

Figure 26: Fuel Consumption for All Transport Demands

Figure 27 shows that passenger transport fuel use grows by 160% between 2012 and 2036, and that LDV fuel use grows to over 80% of all passenger transport energy use, although there is small growth in the other modes.

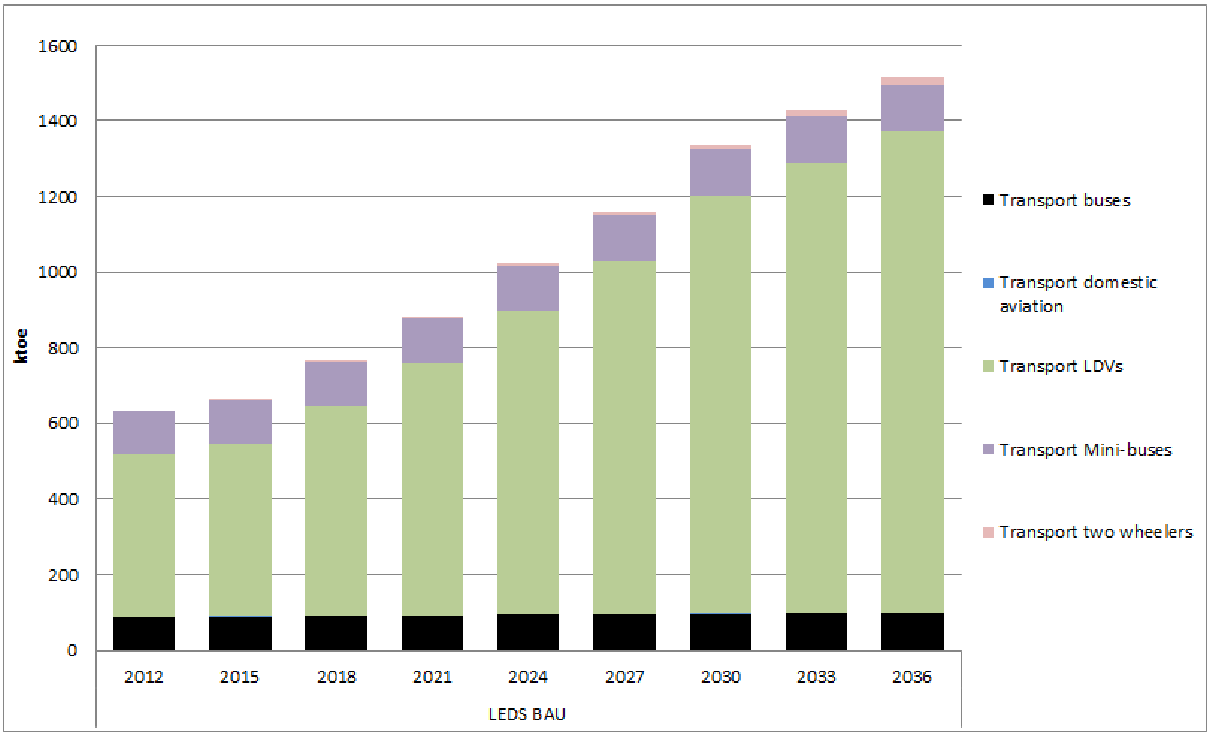

Figure 27: Fuel Use for Passenger Travel by Mode

As shown in Figure 28, passenger transport emissions grow by 125% between 2012 and 2036, with LDVs accounting for over 80% of all passenger transport emissions. These grow less rapidly than the fuel use, as vehicle efficiency improvements and fuel switching from gasoline to CNG results in some emission reductions.

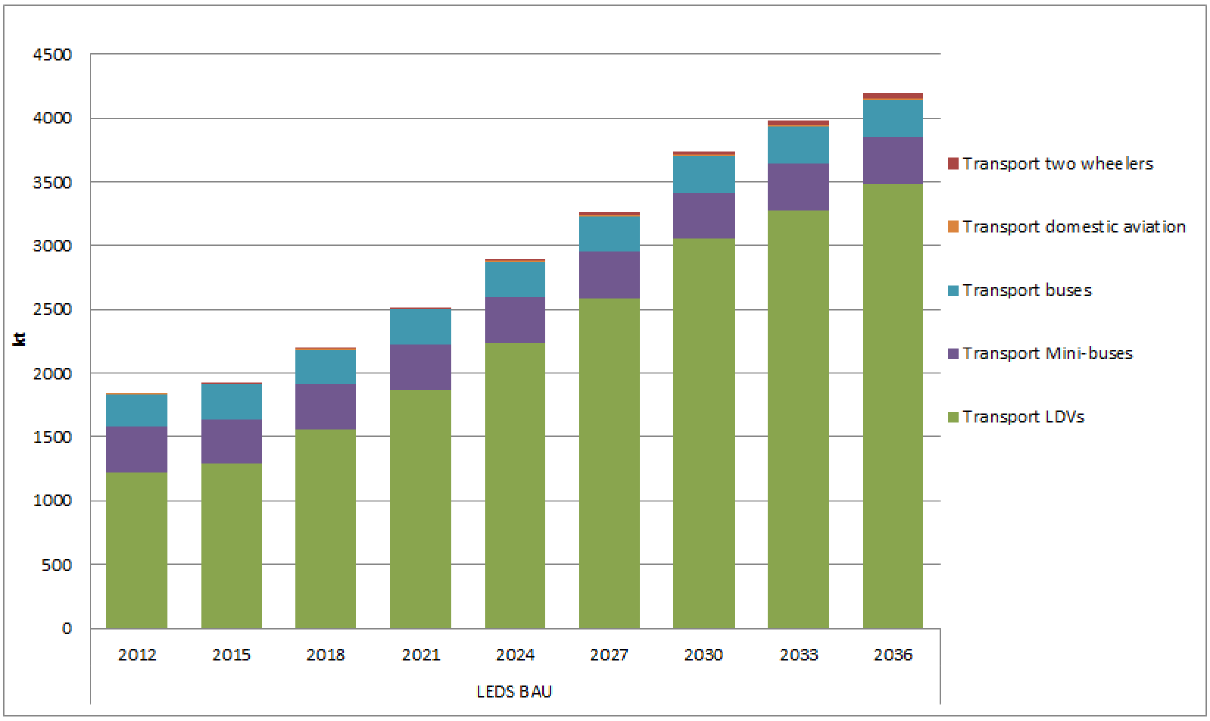

Figure 28: CO_2 Emissions from Passenger Travel by Mode

Figure 29 shows a simplified RES diagram for freight transportation. Each freight transportation demand uses a suite of vehicle types to deliver the associated service.

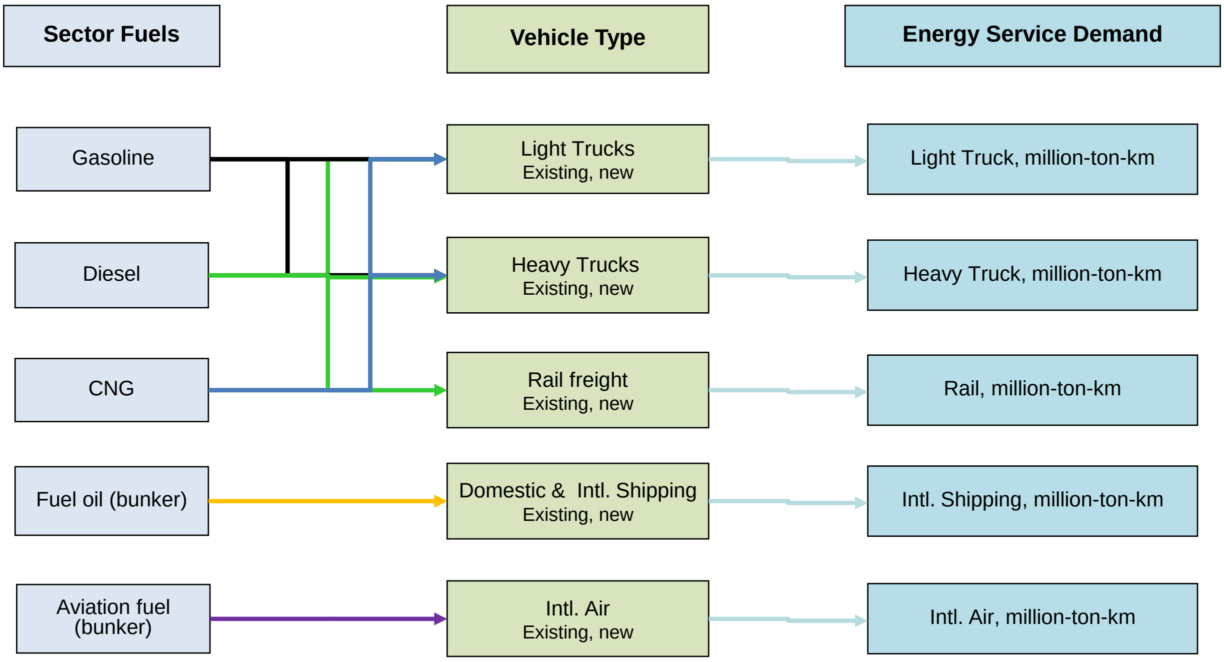

Figure 29: Transportation Freight Traffic RES

Freight transport energy use increases most significantly for natural gas and diesel fuel, although the growth of diesel use is less because of economically driven fuel switching to CNG in light and heavy trucks. As a result, the natural gas share increases to 27% of the total transport fuel use in 2036. Figure 30 shows that freight transport energy use (including bunkers) grows by almost 200% between 2012 and 2036, with light and heavy trucks and international aviation (bunkers) accounting for the bulk of the growth.

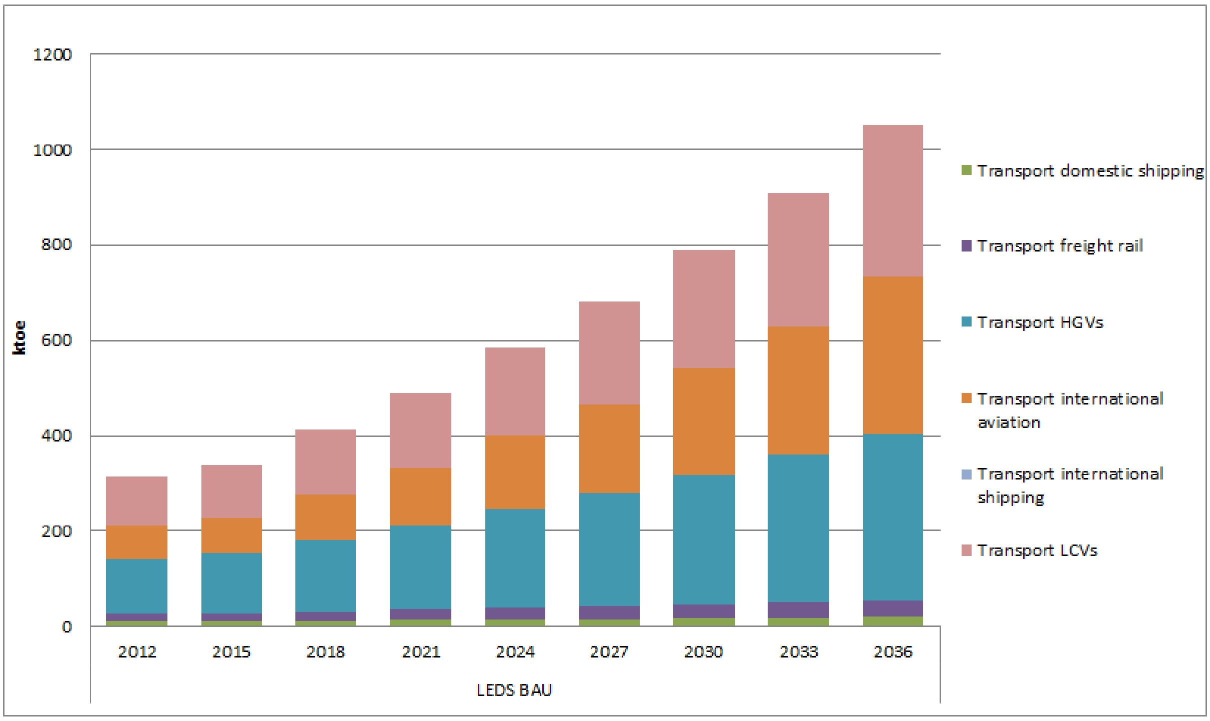

Figure 30: Fuel Consumption for Freight Transport by Mode

As shown in Figure 31, freight transport emissions (excluding bunkers) grow by 190%, with the bulk of the growth coming from light and heavy trucks. International bunker fuels are not counted in the national GHG inventory.

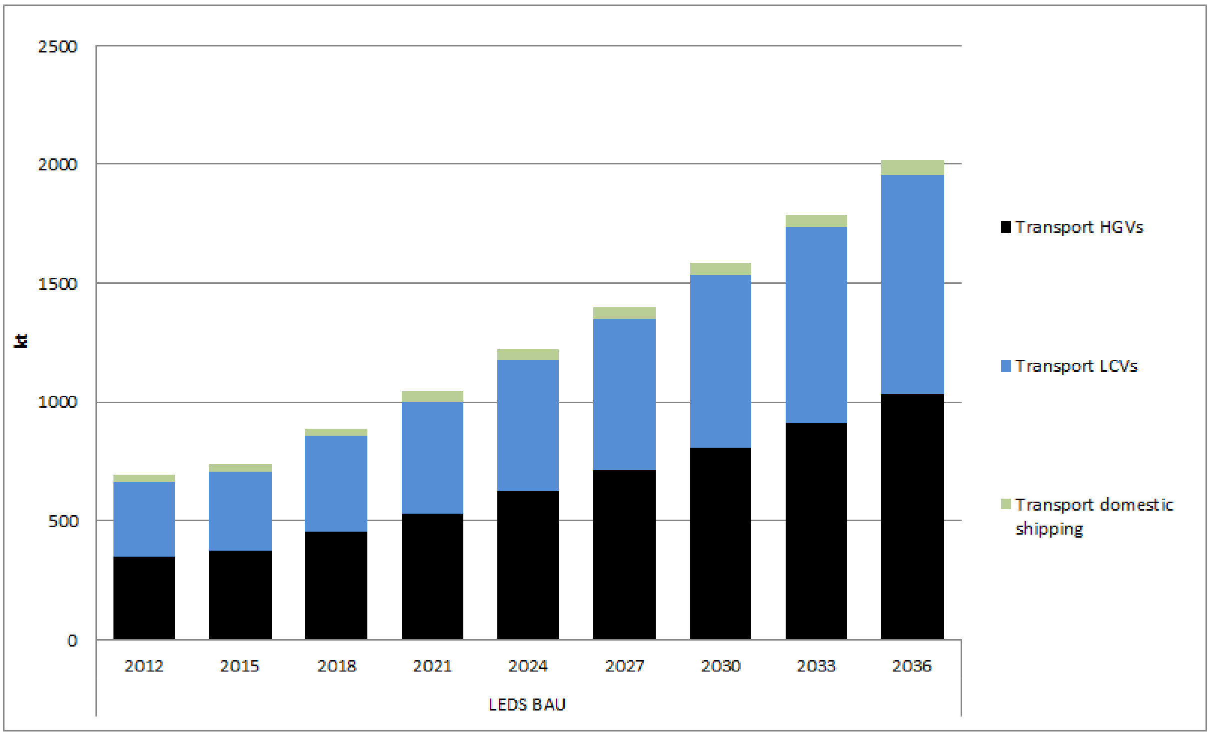

Figure 31: CO_2 Emission from Freight Transport by Mode

ANNEX: ALTERNATE GDP SCENARIOS

This Annex presents summary results for three alternate GDP scenarios. The one requested by the Climate Change Office (CCO) is a refinement of the current BAU scenario, and the others represent optimistic and pessimistic cases for economic growth. Table 2 presents the GDP and population growth assumptions for all four scenarios. An Excel workbook accompanies this report, which provides tabular values for all the charts presented in this report.

Table 2: GDP and Population Growth Assumptions for BAU and Alternate GDP scenarios

BAU Assumptions	**2012**	**2015**	**2018**	**2021**	**2024**	**2027**	**2030**	**2033**	**2036**
GDP growth		2.00%	6.00%	6.00%	6.00%	5.00%	5.00%	5.00%	5.00%
Population growth		0.50%	0.50%	0.50%	0.50%	0.25%	0.25%	0.25%	0.25%
GDP (2012M Euro)	12,323	13,077	15,575	18,550	22,093	25,576	29,607	34,274	39,676
Population (1000s)	4,498	4,565	4,634	4,703	4,774	4,810	4,846	4,883	4,920
GDP/pop	2.740	2.865	3.361	3.944	4.627	5.317	6.109	7.019	8.065
Climate Change Office	**2012**	**2015**	**2018**	**2021**	**2024**	**2027**	**2030**	**2033**	**2036**
GDP growth		2.00%	5.50%	6.12%	6.12%	6.12%	6.12%	6.12%	6.12%
Population growth		0.197%	0.197%	0.197%	0.197%	0.197%	0.197%	0.197%	0.197%
GDP (2012M Euro)	12,323	13,077	15,355	18,351	21,930	26,208	31,321	37,430	44,732
Population (1000s)	4,498	4,524	4,550	4,577	4,604	4,632	4,659	4,687	4,715
GDP/pop	2.740	2.891	3.375	4.009	4.763	5.658	6.722	7.986	9.488
Optimistic Economic Growth	**2012**	**2015**	**2018**	**2021**	**2024**	**2027**	**2030**	**2033**	**2036**
GDP growth		2.00%	8.00%	8.00%	8.00%	7.00%	7.00%	7.00%	7.00%
Population growth		0.50%	0.50%	0.50%	0.50%	0.25%	0.25%	0.25%	0.25%
GDP (2012M Euro)	12,323	13,077	16,473	20,751	26,141	32,024	39,230	48,059	58,874
Population (1000s)	4,498	4,565	4,634	4,703	4,774	4,810	4,846	4,883	4,920
GDP/pop	2.740	2.865	3.555	4.412	5.475	6.657	8.095	9.842	11.967
Pessimistic Economic Growth	**2012**	**2015**	**2018**	**2021**	**2024**	**2027**	**2030**	**2033**	**2036**
GDP growth		2.00%	4.00%	4.00%	4.00%	3.00%	3.00%	3.00%	3.00%
Population growth		0.50%	0.50%	0.50%	0.50%	0.25%	0.25%	0.25%	0.25%
GDP (2012M Euro)	12,323	13,077	14,710	16,546	18,613	20,338	22,224	24,285	26,537
Population (1000s)	4,498	4,565	4,634	4,703	4,774	4,810	4,846	4,883	4,920
GDP/pop	2.740	2.865	3.175	3.518	3.898	4.228	4.586	4.974	5.394

Figure 32 presents the total discounted system cost for the BAU and three alternate GDP scenarios. The CCO case shows almost no difference, while the optimistic economic growth and pessimistic economic growth cases result in about a 15% change over the model horizon.

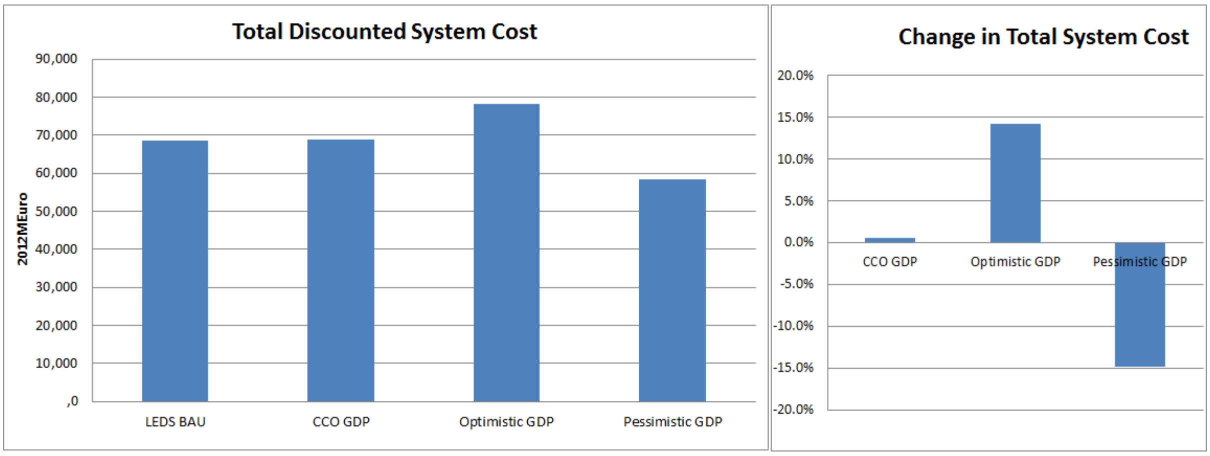

Figure 32: Total Discounted System Cost for BAU and Alternate GDP scenarios

Figure 33 presents the aggregated GHG emissions from the energy system for the BAU and three alternate GDP scenarios. The CCO case shows 8% higher emissions in 2036, while the optimistic economic growth case shows a 20% increase and pessimistic economic growth case results in about a 25% decrease in 2036.

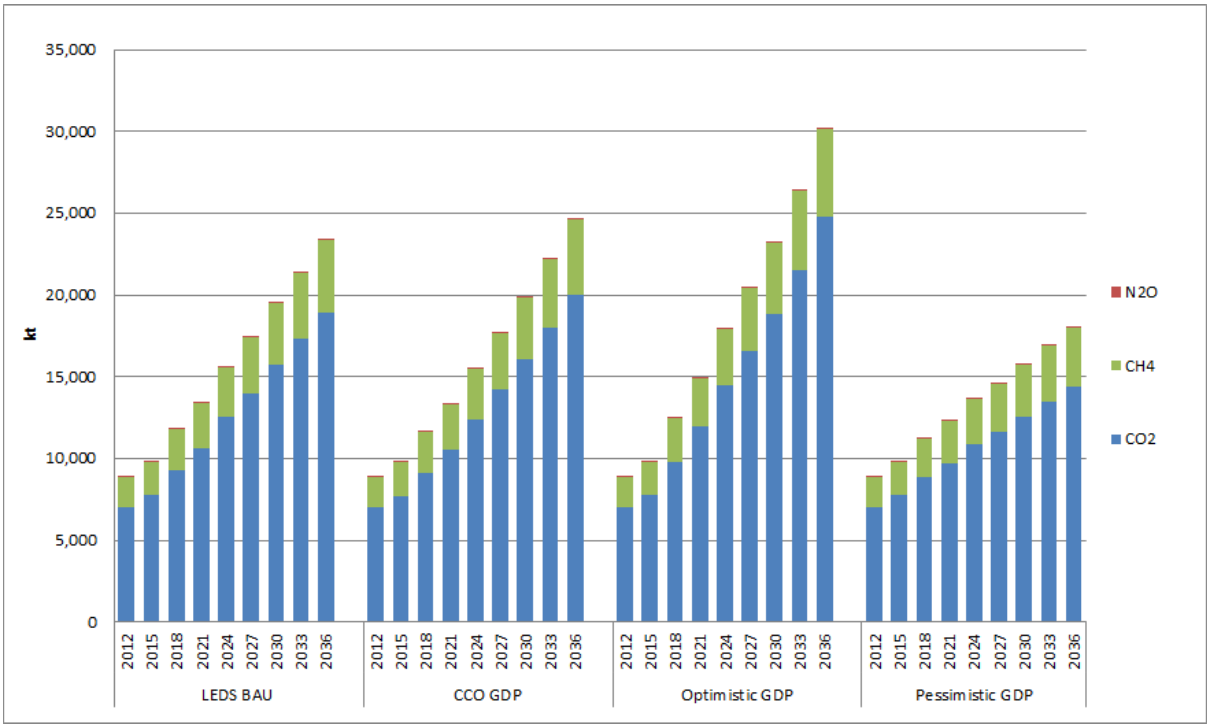

Figure 33: Aggregated GHG Emissions from Energy System for BAU and Alternate GDP scenarios

Figure 34 presents the primary energy consumption for the BAU and three alternate GDP scenarios. The CCO case shows 4.5% higher energy use in 2036, while the optimistic economic growth case shows a 25% increase and pessimistic economic growth case results in about a 20% decrease in 2036.

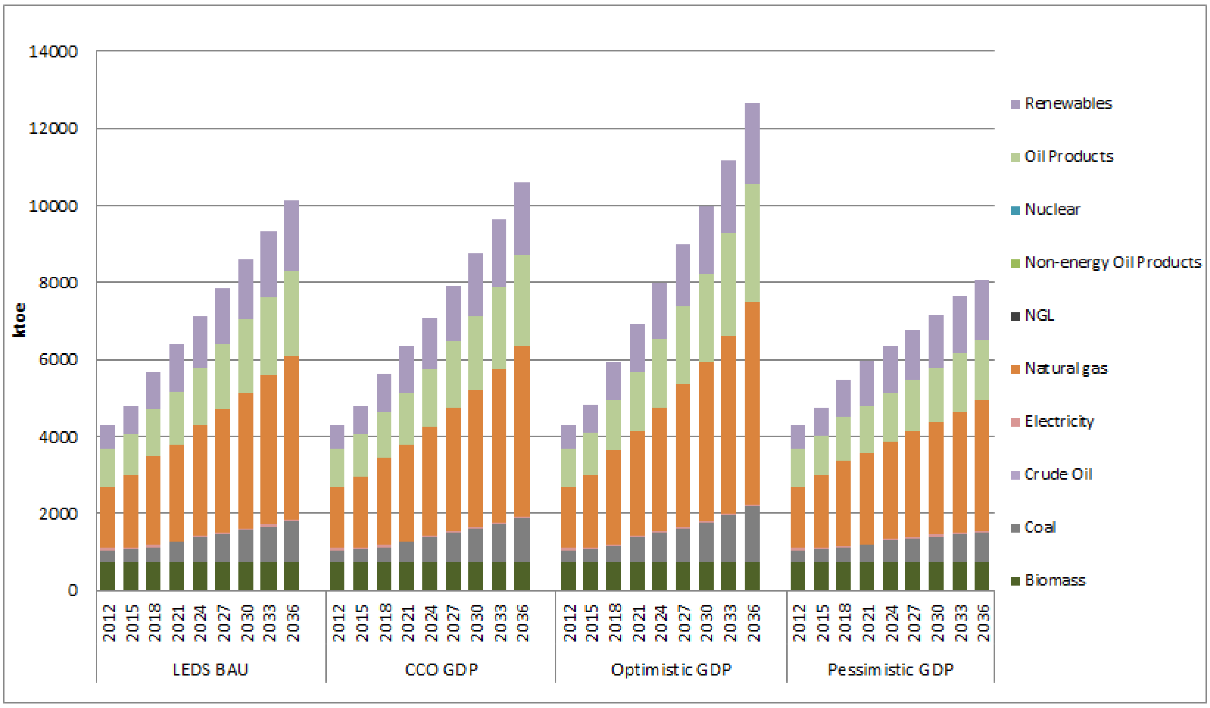

Figure 34: Primary Energy Consumption for BAU and Alternate GDP scenarios

Figure 35 presents the electricity generation by plant type for the BAU and three alternate GDP scenarios. The CCO case shows 5% higher electricity use in 2036, while the optimistic economic growth case shows an 18% increase and the pessimistic economic growth case results in about a 22% decrease in 2036.

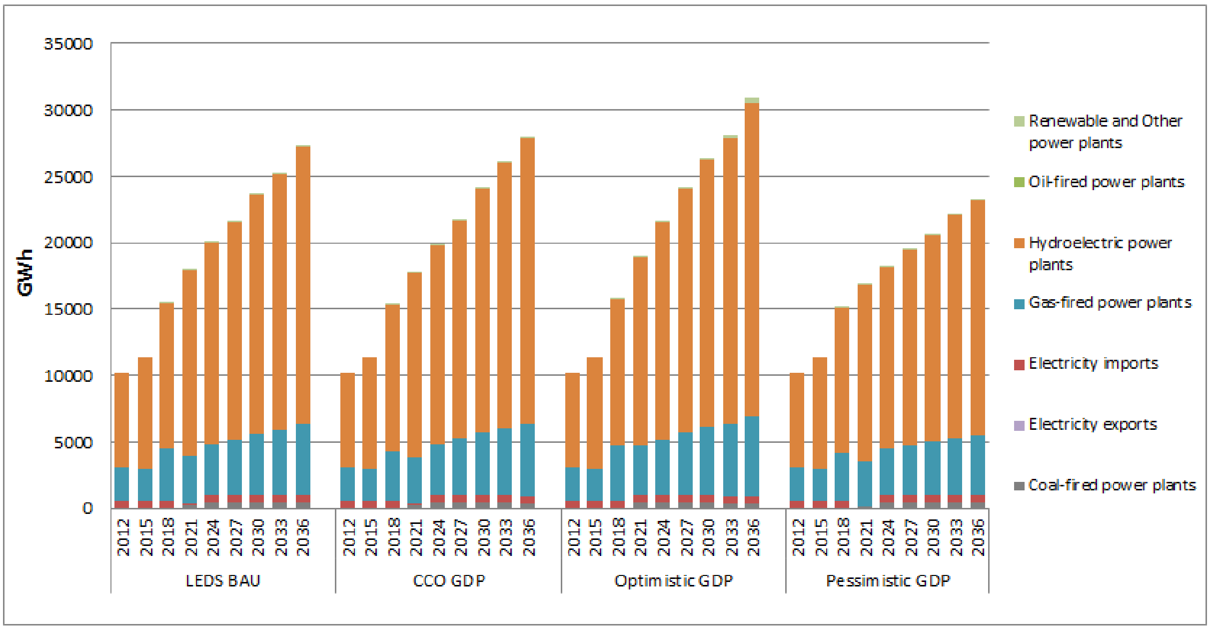

Figure 35: Electricity Generation by Fuel Type for BAU and Alternate GDP scenarios

Figure 36 presents the final energy use for the BAU and three alternate GDP scenarios. The CCO case shows 6% higher energy use in 2036, while the optimistic economic growth case shows a 28% increase and the pessimistic economic growth case results in about a 22% decrease in 2036.

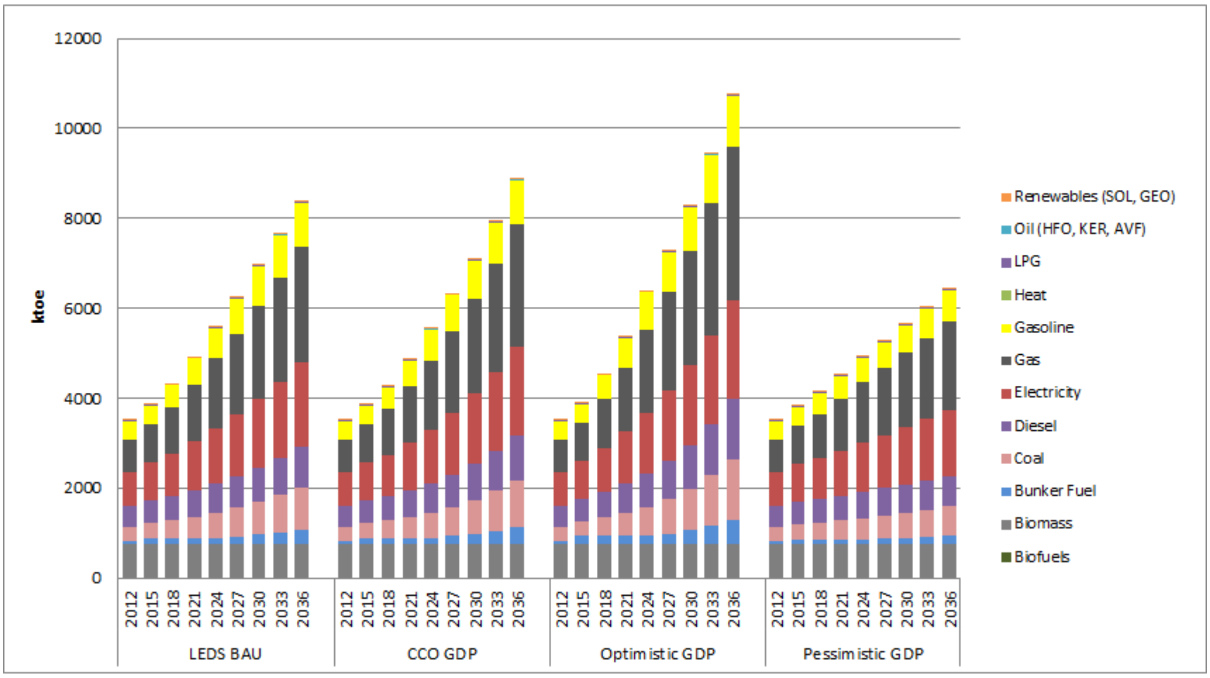

Figure 36: Final Energy Use by Fuel Type for BAU and Alternate GDP scenarios

Figure 37 presents the change in energy intensity for the BAU and three alternate GDP scenarios. The BAU case show a 26% decrease in energy use per GDP in 2036, while the CCO case show a 30% decrease, the optimistic case shows a 36% decrease and the pessimistic economic growth case results in only a 15% decrease in 2036.

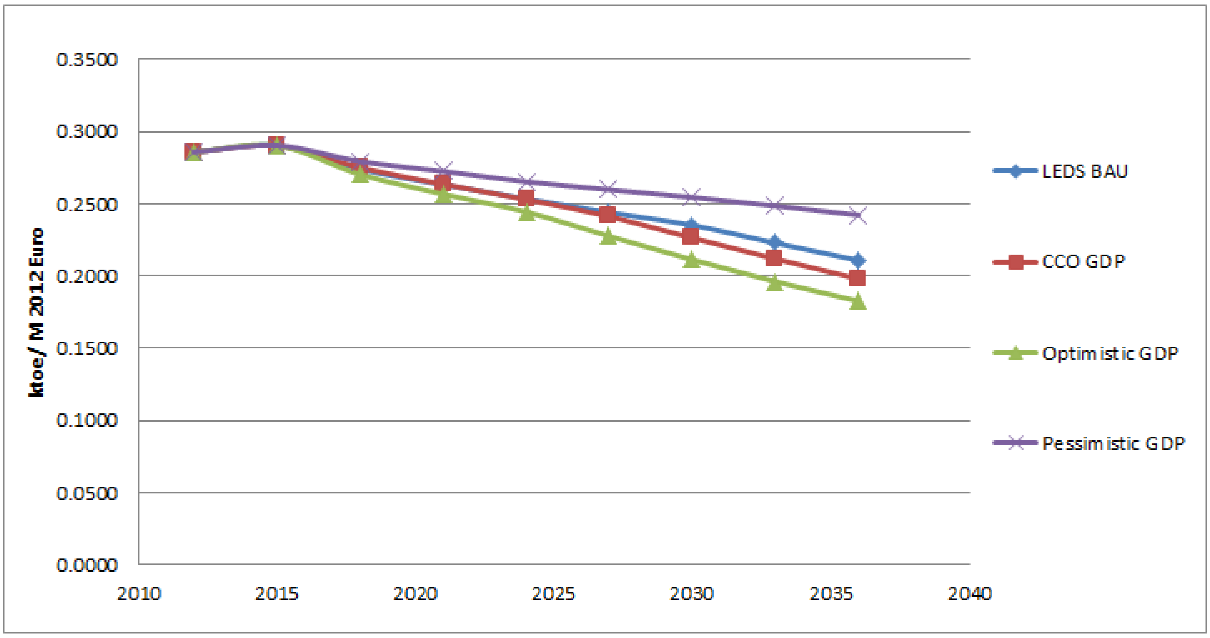

Figure 37: Energy Intensity for BAU and Alternate GDP scenarios